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PERFORMANCE TESTS OF A SIDE-INLET,  
STEAM-TO-AIR JET PUMP WITH AN INBOARD NOZZLE

by A.M. Heinrich

Engineering Report No. 131

for the Office of Naval Research  
Contract N-onr 201(01)

February 1954  
University of Wichita  
School of Engineering  
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## TABLE OF CONTENTS

	Page
LIST OF FIGURES	11
SUMMARY	1
INTRODUCTION	1
SYMBOLS AND SUBSCRIPTS	2
APPARATUS	3
TESTS	
Measurements	4
Data Recorded	5
PERFORMANCE ANALYSIS	5
RESULTS AND DISCUSSION	7
CONCLUSIONS	8
REFERENCES	8
APPENDICES	
A.- Steam Nozzle Design and Calibration	9
B.- Steam Generator and Superheater	16
C.- Test Log of SISA-1 Jet Pump	19
FIGURES	26

## LIST OF FIGURES

Figures	Page
1.- Planform outline; side-inlet, steam-air jet pump.	26
2.- Cross section of SISA-1 jet-pump at nozzle exit.	27
3.- Side-inlet, steam jet pump with an inboard nozzle.	28
4.- Arrangement of mixing-tube pressure taps and throat-adjustment bolts.	29
5.- Exit orifice installation.	29
6.- Arrangement of mixing-tube static pressure taps.	30
7.- Arrangement of suction-slot pressure taps.	30
8.- Suction slot, static-pressure taps and cascaded mixing-tube throat.	31
9.- Multitube manometer with static pressures of suction slot on left and mixing-tube throat on right.	31
10.- Multitube manometer with mixing-tube static pressures on right and inboard suction-slot static pressures on left.	32
11.- Instrumentation schematic.	33
12.- Mixing-tube temperature survey probe.	34
13.- Mixing-tube, total-pressure survey probe.	35
14.- Variation of pressure ratio with mass ratio.	36
15.- Variation of efficiency with mass ratio.	37
16.- Distribution of available energy efficiency.	38
17.- Variation of suction-duct, total-pressure loss with flow quantity.	39
18.- Influence of jet total pressure and pressure ratio on suction-slot quantity distribution.	40
19.- Suction-duct flow pattern with slot and throat throttling.	47
20.- Suction-slot width variation.	48
21.- Mixing-tube entrance throat widths.	50

Figures	Page
22.- Influence of jet total pressure and pressure ratio on throat static-pressure distribution.	51
23.- Influence of jet total pressure and slot throttling on mixing-tube, static-pressure distribution.	53
24.- Influence of jet total pressure and pressure ratio on mixing-tube, total-pressure distribution.	55
25.- Influence of jet total pressure and pressure ratio on temperature distribution.	66

# PERFORMANCE TEST OF A SIDE-INLET, STEAM-TO-AIR JET PUMP WITH AN INBOARD NOZZLE

## SUMMARY

An experimental investigation was conducted to determine the performance of a side-inlet, steam-to-air jet pump with an inboard nozzle. A jet pump with a cylindrical mixing tube was tested for mass ratio, pressure ratio, and efficiency. The transfer of the available energy in the primary flow to the secondary flow and the influence on performance of controlling the direction of secondary air flow into the mixing tube were also investigated.

Performance curves are presented together with curves showing mixing-tube, cross-sectional distributions of temperature and total pressure taken at several survey stations. This report is the first in a series on jet pumps with different taper ratio mixing tubes.

## INTRODUCTION

The application of circulation control to an airplane wing has been proved practical and advantageous. A typical form of application consists of combined sucking and blowing air through slots adjacent to trailing-edge flaps and ailerons (the 'Arado' system). Since the basic structural components of an airplane wing are generally located in the forward area of the wing a pumping system for circulation control may conveniently fit within the area between flaps and ailerons, and the rear span.

The pumping unit for such a circulation control system may take the form of a jet-pump, which is light in weight and simple in operation. The suction section, or intake of the pumping unit, requires a compact arrangement of suction slot and jet-pump mixing tube; this led to the concept of the side-inlet-flow jet pump. A short, direct flow path is thereby provided for the secondary air to the mixing tube. It is the suction duct and mixing tube of such a system that is the subject of this report (see fig. 1). The particular arrangement (SISA-1) involved a cylindrical mixing tube.

A primary fluid with known thermodynamic properties was desirable. This fluid had to have a variable energy level and it was desirable that it be produced by an easily controlled generator. The energy level and characteristics of the primary fluid were to be comparable to those of an actual installation. Superheated steam, since it conveniently simulated products of combustion (of hydrogen peroxide), was selected as the primary fluid.

The purpose of this report was to organize the data and present the test results in a manner usable for subsequent comparative evaluation. Also, the experimental procedures have been explained. The design, construction and tests of the jet pump were performed by the University of Wichita, School of Engineering under the authority of Contract N-onr 201(01) from the Air Branch of the Office of Naval Research.

### SYMBOLS

D	diameter of mixing tube or orifice, inches
L	length of mixing tube, inches
m	mass, slugs
$\rho$	mass density, slugs/ft <sup>3</sup>
Q	heat quantity, BTU
h	enthalpy, BTU/lb
T	absolute temperature, °R
t	temperature °F
$p_t$	total pressure, lbs/ft <sup>2</sup>
p	static pressure, lbs/ft <sup>2</sup>
P	power, ft-lb/sec
W	work, ft-lb
J	mechanical equivalent of heat, 778 ft-lb/BTU
V	velocity, ft/sec
v	local velocity, ft/sec
g	gravitational acceleration, ft/sec <sup>2</sup>
q	volumetric flow rate, ft <sup>3</sup> /sec
w	weight flow rate, lbs/sec
$\alpha$	pressure ratio = $p_{t3}/p_{t0}$
$\mu$	mass ratio = $w_g/w_j$
$\eta$	efficiency = $P_{eff}/P_{in}$



## SUBSCRIPTS

0	free-stream or ambient conditions
1	suction-slot condition
2	mixing-tube-entrance throat condition
3	mixing-tube exit condition
AE	available energy
e	nozzle exit
f	friction
j	primary or jet flow
s	secondary flow
m	mixture of primary and secondary flow
x	axial position from the inboard end of mixing tube
in	input
eff	effective

## APPARATUS

Figures 1 through 8 show the constructional details and arrangement of the side-inlet, stream-to-air jet pump. The principle parts of the model were fabricated from sheet metal and supported by a plywood framework. This assembly was mounted on and held in position with respect to the jet nozzle by an adjustable metal stand attached to the floor.

Schematics of the side-inlet steam jet pumps are shown as figures 1 and 2. The secondary air enters the suction slot, traverses the suction duct and enters the mixing tube through the throat cascade. Within the mixing tube the secondary air mixes with the higher velocity primary jet. Energy of the primary jet is transferred to the secondary air during the mixing process and the mixture is then ejected through the diffuser and blowing tube.

The model physical variables included suction-slot width, mixing-tube entrance throat width, and exit throttle diameter. Width of the suction slot was controlled by adjustment of the intake throttle shown in figure 2. The throat width was controlled by adjustment of the bolts attached to the suction duct at the throat as shown in figures 2 and 4. Figure 5 shows the installation of an orifice-type exit throttle, and figures 6 and 7 show typical test setups.

For the pressure measurements a variety of manometers were used as shown in figures 9 and 10. An instrumentation schematic is given as figure 11. Alcohol was used as the manometer fluid, except in the few cases where mercury was necessary. Ambient air and liquid temperatures were taken with mercury thermometers, while iron-constantan thermocouples were used to measure steam temperatures with an indicating potentiometer.

A total-pressure survey tube and a temperature survey probe were constructed to give approximately the stagnation conditions (i.e., turbulence effects and recovery factor were neglected). It was found necessary to insulate the temperature probe tip from the brass body to reduce heat transfer. Phenolic fiber was satisfactory for this purpose.

The primary fluid (superheated steam) was supplied by a Besler Corporation steam-generator-superheater system. These units supplied steam at pressures from 225 to 325 psig with temperatures from saturation to 650°F. A description of this equipment is given in Appendix B and reference 2. The steam nozzles were designed, fabricated and calibrated as described in Appendix A.

#### TESTS

The test procedures and data recording were in accordance with the pre-test report (Ref. 1). Initial adjustments of the throat and slot widths were accomplished in a series of short runs to obtain the desired suction-slot flow-quantity distribution. The maximum mass ratio was obtained by adjustments of the suction-slot throttle rather than the entrance throat. Suction-slot throttling was used for all tests subsequent to this initial investigation, even though secondary-flow-quantity distribution was more difficult to obtain with suction-slot throttling, and large spanwise slot-width variations were required.

The following measurements and variations to the model configuration were then performed.

- Measurements. -
1. Suction slot area.
  2. Mixing-tube-entrance throat area.
  3. Suction slot static-pressure distribution.
  4. Mixing-tube entrance throat static-pressure distribution.
  5. Mixing-tube cross-sectional, total-pressure distribution.
  6. Configuration changes:  
 Repetition of the above measurements in successive steps from the condition of an open exit tube to a condition of restricted exit producing incipient reverse flow in the suction slot.

Data Recorded. - All data listed under 'Measurements' were recorded, together with the following:

1. Suction-slot air temperature.
2. Throat air temperature.
3. Mixing-tube-flow temperature distribution at each survey station.
4. Steam temperature.
5. Steam pressure.
6. Barometric pressure.

#### PERFORMANCE ANALYSIS

The jet-pump performance parameters were detailed in the pretest report (Ref. 1). The influence of specific impulse on performance will be evaluated later. Total-pressure losses in the suction duct were determined from average velocities and pressures found by integrating the flow-quantity distribution curves. The throat flow distribution was not similar to the slot distribution because of cross flow in the suction duct (Fig. 25). Therefore, the spanwise variation of the losses was not determined.

The average suction-duct losses were determined by the following procedure-

a) Bernoulli's equation at the suction<sub>2</sub> slot is

$$p_{t0} = p_{t0} + p_1 + \frac{\rho_1 v_1^2}{2}, \text{ or, } -p_1 = \frac{\rho_1 v_1^2}{2}.$$

This relation was used to calculate the suction slot velocities which then gave the secondary flow quantity by integration across the slot.

b) The suction-slot quantity was temperature corrected for conductive heating effects by

$$q_2 = q_1 \frac{T_2}{T_1}, \text{ since the flow was essentially}$$

incompressible.

c) Then an average throat velocity was calculated from

$$v_2 = \frac{q_2}{A_2}.$$

d) Finally, the approximate total-pressure loss in the suction duct resulted from the relation

$$\Delta p_t = p_{t1} - p_{t2} - p_{t0} - \left[ (p_{t0} + p_2) + \frac{1}{2} \rho_2 v_2^2 \right] = -p_2 - \frac{1}{2} \rho_2 v_2^2$$

The efficiency of the jet pump was determined from the ratio of effective power output to power input. The effective power output was defined as the summation of the products of the primary and secondary flow quantities and their respective adiabatic pressure changes (Ref. 1):

$$P_{\text{eff}} = q_s (p_{t3} - p_{t1}) + q_j (p_{t3} - p_{t0}).$$

The power input (Ref. 1) was defined as the product of the primary weight flow rate and the enthalpy change through the nozzle, where the enthalpy change included the effects of friction:

$$P_{\text{in}} = w_j \Delta h_j.$$

The efficiency was therefore-

$$\eta = \frac{P_{\text{eff}}}{P_{\text{in}}} = \frac{q_s(p_{t3} - p_{t1}) + q_j(p_{t3} - p_{t0})}{w_j \Delta h_j}.$$

The mass ratio was expressed by the secondary to primary weight flow ratio,

$$\mu = \frac{w_s}{w_j}.$$

The available-energy efficiency at any point in the mixing tube was the ratio of the local available energy of the mixture to the available energy of the primary flow at the nozzle. This efficiency varied through the mixing tube as the primary-flow energy was transferred and dissipated by the mixing process. At any point the available energy was the sum of the kinetic energy and pressure. The energy ratio was

$$\eta_{\text{AE}_x} = \frac{\frac{1}{2} \rho_{m_x} V_{m_x}^2 + p_{m_x}}{\frac{1}{2} \rho_j V_j^2}.$$

The change of available energy through the mixing tube indicated the amount of energy transferred from the primary flow by adiabatic compression minus that dissipated by turbulence.

The jet-pump pressure ratio was defined as the ratio of the mixed-flow total pressure to the ambient total pressure

$$\alpha = \frac{p_{t3}}{p_{t0}}.$$

## RESULTS AND DISCUSSION

Figures 14 through 17 show the performance of the side-inlet jet pump tested. The secondary mass flow increased as a function of the primary mass flow (fig. 18), but the mass ratio decreased due to the increase in pressure ratio (fig. 14). The pressure ratio increase resulted from forcing larger quantities of mixture through the same blowing-tube exit area. The effects of greater pressure ratios are given by figures 14 and 15. The highest pressure ratio was measured at the point of incipient reverse flow in the suction slot. Higher pressure ratios would have resulted in a rapid decrease in mass ratio.

Figure 18 shows the influence of the variables of primary pressure, pressure ratio, slot throttling, throat throttling, and cascades on suction-slot quantity distributions. Comparison of secondary-flow distributions secured by adjustments of the throat and/or the slot showed that slot adjustment for desired quantity distribution with constant throat produced the most secondary flow quantity, and therefore the largest mass ratio. This may not be true for a tapered mixing tube since the mixing-tube flow conditions control the suction-duct flow.

Cascades in the inboard 12 inches of throat critically influenced the performance while the remainder had only a slight influence on the performance. Removal of all the cascades caused intermittent reverse flow in the outboard throat area and a strong ring-vortex in the mixing tube at the inboard end around the nozzle flow.

Figure 19 shows the influence of slot throttling on the direction of air flow in the suction duct. The variations of the slot and throat widths to obtain the desired quantity distributions are shown in figures 20 and 21.

The throat and mixing-tube static pressure distributions, figures 22 and 23, showed that most of the mixing took place within the inboard 16 inches of the mixing tube. Available-energy efficiency distribution also showed this to be true (Fig. 16). This 'effective' mixing zone appears in all jet-pumps (Refs. 4 and 5). Although pressure surveys were not taken inboard of station 16 the mixing-tube surface temperatures indicated that the effective mixing zone extended 12 inches downstream from the nozzle. The end of the effective mixing zone is usually considered as the point where the mixed flow first fills the entire tube cross section.

Cross-section survey profiles of total pressure and temperature in the mixing tube are shown in figures 24 and 25. Average values of the integrated horizontal and vertical profiles of the total pressure distribution combined with the static pressure were used to roughly calculate the local available energy of the mixing tube flow. The temperature surveys were taken to supplement the total pressure surveys for the study of mixing characteristics. In figure 25 the temperature profiles indicate by their magnitude the areas of mixed and unmixed flow. The areas of unmixed flow, indicated by low temperatures, were adjacent to the mixing-tube entrance throat.

The performance of the steam-to-air jet pump-tested was not considered optimum because of rough surfaces, sharp corners, etc. However, the performance analysis for a tapered mixing-tube jet-pump of similar construction will show comparatively the importance of mixing-tube shape. Also, these analyses will show the relative merits of secondary flow guidance and distribution methods.

#### CONCLUSIONS

Tests of a side-inlet, steam-to-air jet pump with an inboard nozzle and a cylindrical mixing-tube have shown this arrangement to have high losses and poor suction-slot, quantity-distribution properties. The high losses were ascribed to the extreme suction-slot throttling required for intake flow-quantity distribution and to the uncontrolled dissipation of the primary flow in the first part of the mixing-tube.

Further tests should be conducted with various taper-ratio mixing-tubes to determine the influence of this factor on the control of the mixing process and secondary flow-quantity distribution.

#### REFERENCES

- 1.- Heinrich, A.M.: Pre-Test Report on the Performance Study of a Side-Inlet Jet Pump with an Inboard Nozzle. University of Wichita Engineering Study No. 117, October 1953.
- 2.- Wagner, Friedrich; McGune, Charles J.: A Progress Report on Jet Pump Research. University of Wichita Engineering Report No. 085, October 1952.
- 3.- Everett, H.A.: Thermodynamics. D. Van Nostrand Co., Inc., New York, 1948.
- 4.- Wagner, F.: A Contribution to the Development of Jet Pumps. ATI No. 20253, July 1944.
- 5.- Helmbold, H.B.: Contributions to Jet Pump Theory, III. Simplified Theory of Mixing-Zone Spreading. University of Wichita Engineering Report No. 107, July 1953.

APPENDIX A  
STEAM NOZZLE DESIGN AND CALIBRATION



## STEAM NOZZLE DESIGN AND CALIBRATION

The design of the supersonic steam nozzle was based on the adiabatic expansion of superheated steam through a convergent-divergent passage. The flow was corrected for the entropy increase due to wall friction. Since very little of the expansion was to take place in the saturated or supersaturated region, the losses for droplet lag and supersaturation were considered negligible. The upstream velocity was also negligible since it was small compared to the nozzle velocity.

Given: Nozzle as shown in figure A1 and,

1. Quantity - 810 lbs/hr
2. Initial state pressure - 300 psia
3. Initial state temp. - 650°F
4. Final state pressure - 14.7 psia
5. Nozzle efficiency 96 percent (4 percent friction loss).

From steam tables or Mollier diagram:

$$s_1 = 1.652 \text{ Btu/lb} = \text{initial state entropy}$$

$$h_1 = 1342 \text{ Btu/lb} = \text{initial state enthalpy}$$

for superheated steam with  $k = 1.3$

$$p_{th}/p_{t1} = 0.545$$

where  $p_{th}$  = throat pressure

$p_{t1}$  = initial state pressure

$$p_{th} = .545 \times 300 = 163.5 \text{ psia}$$

$$s_{th} = s_1 = 1.652 \text{ Btu/lb } ^\circ\text{F}$$

$$t_{th} = 504^\circ\text{F}$$

$$v_{th} = 3.382 \text{ ft}^3/\text{lb} = \text{throat specific volume}$$

$$h_{th} = 1274.87$$

$$V_{th} = \sqrt{2gJ(h_1 - h_{th})} \quad \text{when } h_2 = h_{th}$$

$$V_{th} = 224 \sqrt{1342 - 1274.87} = 1840 \text{ ft/sec}$$

$$A_{th} = \frac{810 \times 3.382 \times 144}{3600 \times 1840} = .0596 \text{ in}^2$$

$$\text{dia}_{th} = \sqrt{\frac{.0596 \times 4}{\pi}} = .2755 \text{ inches}$$

$$h_e = 1080 \text{ Btu/lb}$$

$$V_e = 224 \sqrt{1342 - 1080} = 3620 \text{ ft/sec}$$

$$\text{quality } x_e = \frac{s_1 - s_{f2}}{s_{fg2}} \times 100 = 92.75 \text{ percent}$$

$$v_e = v_{fe} + x_e v_{fg_e}$$

$$v_e = .02 + (.9275)(26.8) = 24.87 \text{ ft}^3/\text{lb}$$

$$A_e = \frac{810 \times 24.87 \times 144}{3600 \times 3620} = .223 \text{ in}^2$$

$$\text{dia}_e = \sqrt{\frac{.223 \times 144}{\pi}} = .533 \text{ in}$$

#### THROAT AREA CORRECTION FOR FRICTION

$$P_{th} = 163.5 \text{ psia}$$

$$V_{th} = 224 \sqrt{.96 \times 67.13} = 1800 \text{ ft/sec}$$

$$\text{Reheat to throat} = .04 \times 67.13 = 2.685 \text{ Btu/lb}$$

$$h_{th} = 1274.87 + 2.685 = 1277.56 \text{ Btu/lb}$$

$$t_{th} = 510^\circ\text{F}$$

$$v_{th} = 3.416 \text{ ft}^3/\text{lb}$$

$$A_{th} = \frac{810 \times 3.416 \times 144}{3600 \times 1800} = .0615 \text{ in}^2$$

$$\text{dia}_{th} = \sqrt{\frac{.0615 \times 144}{\pi}} = .280 \text{ in}$$

#### EXIT AREA CORRECTION FOR FRICTION

$$V_e = 224 \sqrt{.96 \times 262} = 3550 \text{ ft/sec}$$

$$\text{Reheat to exit} = .04 \times 262 = 10.5 \text{ Btu/lb}$$

$$h_e = 1080 + 10.5 = 1090.5$$

$$x_e = 100 - 6.5 = 93.5 \text{ percent}$$

$$v_e = .02 + (.935)(26.8) = 25 \text{ ft}^3/\text{lb}$$

$$A_e = \frac{810 \times 25 \times 144}{3600 \times 3550} = .229 \text{ in}^2$$

$$\text{dia}_e = \sqrt{\frac{.229 \times 144}{\pi}} = .54 \text{ in}$$

The nozzle layout was arbitrarily selected to give a smooth round entrance to the throat and a straight taper from the throat to the exit. Figure A1 shows the cross-section of the nozzle. The nozzle was machined from stainless steel with extreme internal dimensional control and then polished.

A nozzle calibration was performed through timed measurement of inlet and waste flow of water to the stream generating unit. These flow rates were determined at various pressures and temperatures and plotted as figures A2 and A3.

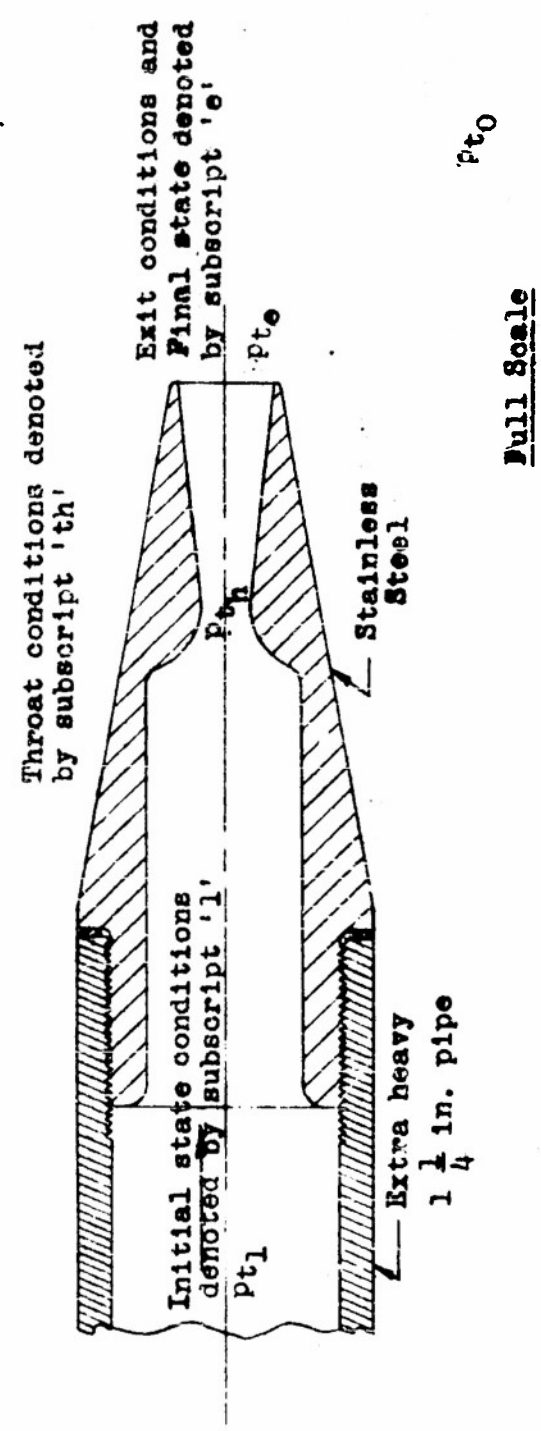


Figure A1. - Cross section, convergent-divergent steam nozzle.

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VARIATION OF FLOW  
WITH STEAM PRESSURE  
CONVERGENT-DIVERGENT NOZZLE  
STEAM TEMPERATURE 600°F

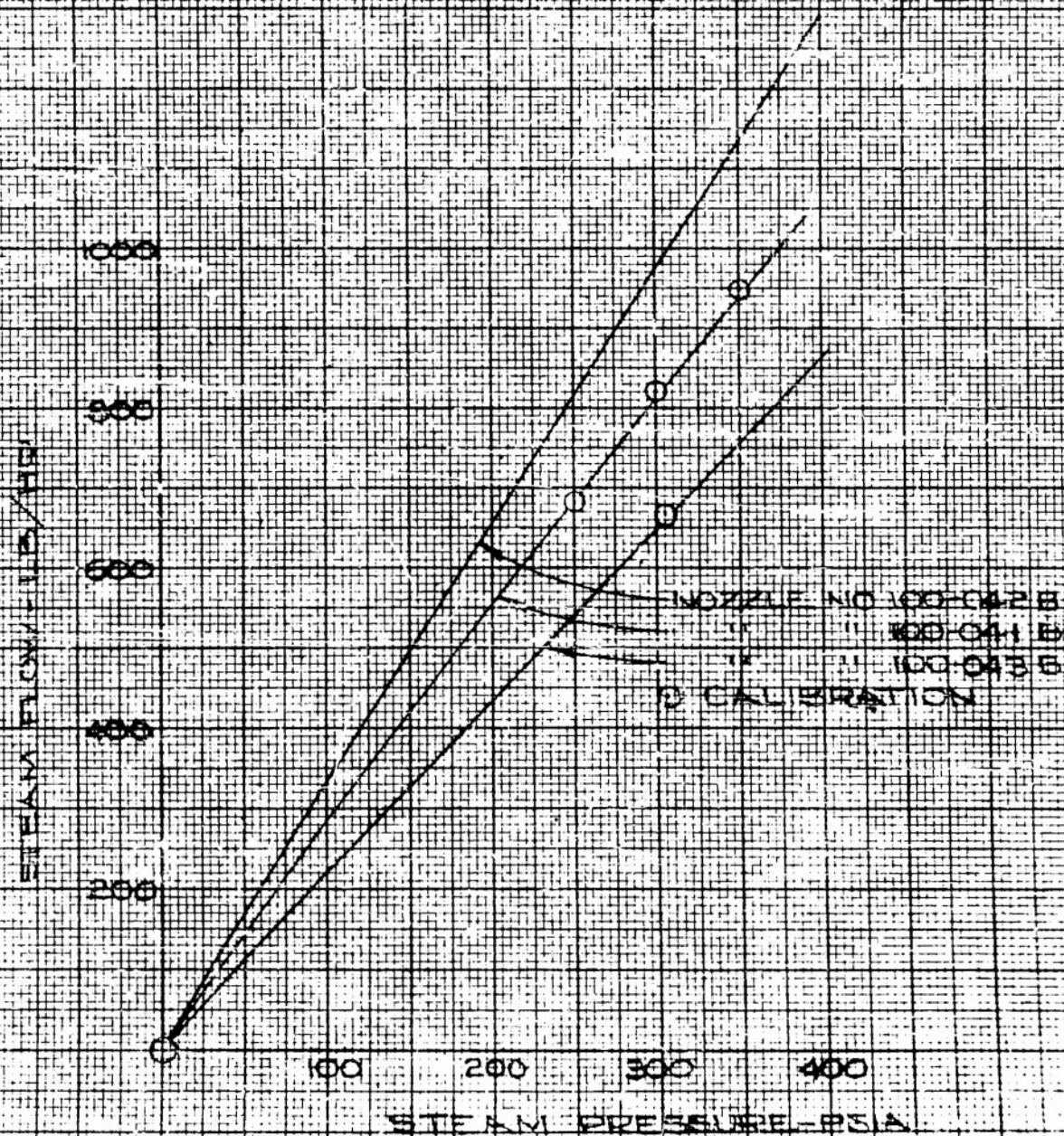


FIGURE A2

MM 2-10-56

K&E

KENT & EDDY CO.  
10 X 10 TO LINE 1/4 INCH

REVISION  
320-11



UNIVERSITY OF WICHITA  
SCHOOL OF ENGINEERING  
EFFECT OF TEMPERATURE  
ON STEAM FLOW

○ 650 °F  
□ 690 °F  
△ 800 °F

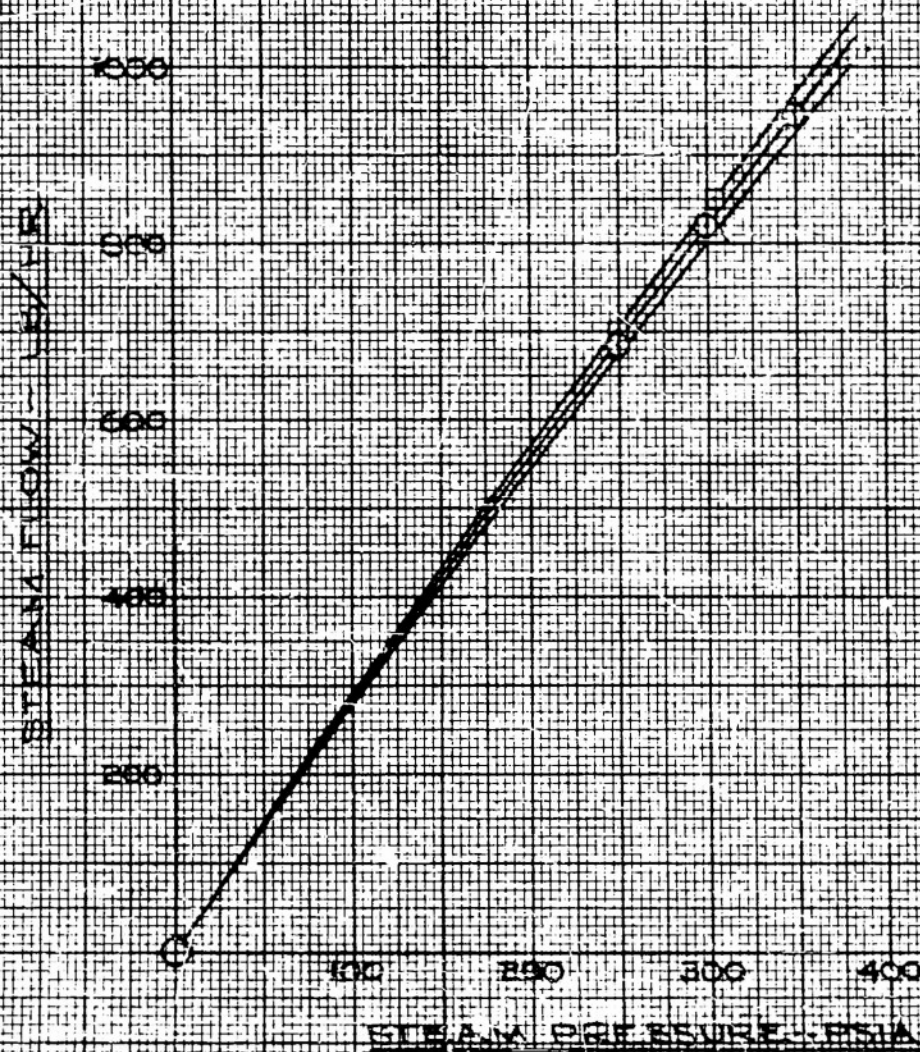


FIGURE A2

AKA 2-11-5A

K-E  
KENDRICK & EMMES CO.  
10 X 10 TO THE 11 INCH  
7700 R.T.V.  
380-11

APPENDIX B

STEAM GENERATOR AND SUPERHEATER



### STEAM GENERATOR AND SUPERHEATER

Steam for the primary fluid was produced by a Besler Model 85 generator (Fig. B1). This generator is a package unit containing the boiler, auxiliaries, and auxiliary drive motor incorporated within a single framework. The unit is regulated by an air-operated, modulation control system. The control system will maintain a constant-pressure supply of steam at a given flow rate up to a maximum of 2500 pounds per hour. A change in either the pressure and/or the flow rate requires readjustment of the control system.

A Besler superheater (Fig. B2) was used to superheat the steam. It is a small, compact unit that burns diesel fuel and uses 110-volt single-phase power for operation. An electric motor drives the blower and fuel pump and the 110 volt power is transformed to 10,000 volts and imposed across a set of electrodes for combustion-chamber ignition. Temperature control is obtained by a thermostatically actuated fuel bleed control. Manual adjustment of the spring tension in this device regulates the fuel flow. The unit with its integral fuel tank is portable and requires only the availability of 110-volt, single-phase power for operation.

The rectangular manifold over the waste steam line shown in figure B1 is a condenser used to facilitate measurement of the generator waste flow for nozzle calibration purposes.



Figure B1. - Steam generator.



Figure B2. - Steam superheater and generator.

## APPENDIX C

## TEST LOG OF SISA-1 JET PUMP

Runs SISA-1-1 through SISA-1 27

## TEST LOG, SISA-1 JET PUMP

<u>Run No.</u>	<u>Configuration</u>	<u>Remarks</u>
1	Throat width A. Slot width 1.6 inches, constant.	Outboard suction slot flow too small to measure.
2	Throat width B. Slot width 1.6 inches, constant.	Entire suction slot flow too small to measure.
3	Throat width B. Slot width 0.8 inches, constant.	Suction slot flow dis- tribution measured. Distribution fairly constant over inboard half of suction slot and diminishing to negligible flow at outboard end of slot.
4	Throat width C. Slot shape throttle A.	Suction slot flow dis- tribution measured.
5	Throat width C. Slot shape throttle B.	Suction slot flow dis- tribution recorded. Mixing tube static pressure gradient recorded.
6	Throat width C. Slot shape throttle B. Sonic nozzle this run only.	Suction slot flow. Distribution recorded. Mixing tube static pressure gradient recorded. Nozzle flow case of extreme under-expansion.
7	Throat width C. Slot shape throttle C.	Suction duct outboard of station 42.3 blocked off. Measurements: a. Suction slot flow b. Mixing tube static pressure c. Total pressure survey at mixing tube station A (vertical only).
8	Throat width C. Slot shape throttle D.	Measurements: a. Suction slot flow b. Mixing tube static pressure distribution.
9	Throat width C. Slot shape throttle E.	Measurements: a. Suction slot flow b. Mixing tube static pressure distribution.

<u>Run No.</u>	<u>Configuration</u>	<u>Remarks</u>
10	Throat width C. Slot shape throttle F.	Total pressure probe tube diameter increased to prevent moisture clogging. Measurements: a. Suction slot flow b. Mixing-tube static pressure c. Mixing-tube total pressure distribution at stations A and D.
11	Throat width C. Slot shape throttle F.	Measurements: Same as 10 except total pressure taken at stations A through D.
12	Throat width C. Slot shape throttle F.	Temperature probe tried and found to have intolerable heat transfer from body to tip. Measurements: a. Mixing-tube total pressure distribution taken at stations E and F. b. Mixing-tube temperature taken at stations A through F.
13	Throat width C. Slot shape throttle F.	Temperature probe with phenolic insulated tip proved satisfactory. Measurements: Temperature survey taken at mixing-tube stations A through F.
14	Throat width C. Slot shape throttle F.	Suction duct flow direction studied with a wool tuft. Measurements: a. Temperature and total pressure survey taken at mixing tube station F. b. Suction slot flow c. Mixing-tube static pressure distribution d. Suction slot temperature distribution.

<u>Run No.</u>	<u>Configuration</u>	<u>Remarks</u>
15	Throat width C. Slot shape throttle F.  Cascaded turning vanes removed from throat.	Intermittent reverse flow at outboard end of suction slot. Surface temperature and static pressure of mixing tube at inboard end showed evidence of a strong vortex within first 6 inches of mixing tube length. Measurements: a. Suction slot flow b. Mixing tube static pressure distribution. c. Suction slot average temperature.
16	Throat width C. Slot shape throttle F.  Cascaded turning vanes in inboard 12 inches of throat only.	No reverse flow in suction slot. No evidence of the vortex as found in Run 15. Suction duct flow was studied with a wool tuft. Measurements: a. Suction slot flow b. Mixing tube static pressure distribution c. Suction slot average temperature.
17	Throat width C. Slot shape throttle F.  Cascaded turning vanes in inboard 20 inches of throat only	Similar characteristics of Run 16. Suction duct flow was studied with a wool tuft. Measurements: a. Suction slot flow b. Mixing tube static pressure distribution c. Suction slot average temperature.
18	Throat width C. Slot shape throttle F. Cascaded turning vanes in inboard 12 inches of throat only.	Verification of Run 16.
19	Throat width C. Slot shape throttle F. All cascaded turning vanes installed.	Performance run. Measurements: Steam $p_{tj}$ = 224 psig $t$ = 653°F a. Suction slot flow b. Mixing tube entrance throat static pressure distribution

<u>Run No.</u>	<u>Configuration</u>	<u>Remarks</u>
		c. Mixing tube static pressure distribution. d. Mixing tube temperature and total pressure survey at stations A through F.
20	Throat width C. Slot shape throttle F. All cascaded turning vanes installed.	Performance run. Measurements: Same as for Run 19. Steam $pt_j = 253$ psig, $t = 660^\circ\text{F}$ .
21	Throat width C. Slot shape throttle F. All cascaded turning vanes installed.	Performance run. Measurements: Same as for Run 19. Steam $pt_j = 275$ psig, $t = 653^\circ\text{F}$ .
22	Throat width C. Slot shape throttle F. All cascaded turning vanes installed.	Performance run. Measurements: Same as for Run 19. Steam $pt_j = 300$ psig, $t = 657^\circ\text{F}$ .
23	Throat width C. Slot shape throttle F. All cascaded turning vanes installed.	Performance run. Measurements: Same as for Run 19. Steam $pt_j = 327$ psig, $t = 660^\circ\text{F}$ .
24	Throat width C. Slot shape throttle F. All cascaded turning vanes installed. Two different sizes of exit orifices were installed.	Test to establish maximum pressure ratio for incipient reverse flow in section slot. Measurements: a. Suction slot flow b. Mixing tube static pressure distribution
25	Throat width C. Slot shape throttle F. All cascaded turning vanes installed. Exit orifice diameter ratio = 1.0.	Reference run for Runs 26 and 27. Measurements: Steam $pt_j = 303$ psig $t = 653^\circ\text{F}$ a. Suction slot flow b. Mixing tube entrance throat static pressure distribution c. Mixing tube static pressure distribution d. Mixing tube temperature and total pressure survey at station F.



24

<u>Run No.</u>	<u>Configuration</u>	<u>Remarks</u>
26	Same as Run 25 except exit orifice diameter ratio = .908	Performance test with additional pressure ratio. Measurements same as for Run 25.
27	Same as Run 25 except orifice diameter ratio = .824	Performance test with additional pressure ratio. Measurements same as for Run 25.

TABLE C1.- SISA-1 JET PUMP PERFORMANCE

Run No.	pt <sub>j</sub> (psia)	t <sub>j</sub> (°F)	w <sub>s</sub> (lb/sec)	w <sub>j</sub> (lb/sec)	w <sub>s</sub> /w <sub>j</sub>	pt <sub>3</sub> /pt <sub>0</sub>	η
1	300	650					
2	300	650					
3	300	650					
4	315	650					
5	315	650					
6	314	650					
7	314	650	1.765	0.235	7.51		
8	314	650	1.740	0.235	7.40		
9	314	650	1.710	0.235	7.28		
10	314	650	1.77	0.235	7.53		
11	314	650	1.74	0.235	7.40		
12	314	650	-----	0.235	-----		
13	314	650	-----	0.235	-----		
14	314	650	1.765	0.235	7.51		
15	314	650	1.140	0.235	4.85		
16	314	650	1.80	0.235	7.66		
17	314	650	1.72	0.235	7.32		
18	314	650	1.75	0.235	7.45		
19	238	653	1.315	0.179	7.35	1.0045	0.625
20	266.9	660	1.44	0.200	7.20	1.0055	0.788
21	289	653	1.46	0.2165	6.74	1.0055	0.751
22	314.2	657	1.65	0.235	7.02	1.0059	0.871
23	341.7	660	1.765	0.2555	6.9	1.0062	0.905
24	300	415	-----	-----	-----	-----	-----
25	316.9	653	1.645	0.228	7.2	1.005	0.915
26	315.9	652	1.498	0.228	6.56	1.01	1.42
27	315.9	651	1.345	0.228	5.9	1.014	1.88

Approximate values + 5°F and ± 5 psi  
Runs No. 1 through 18



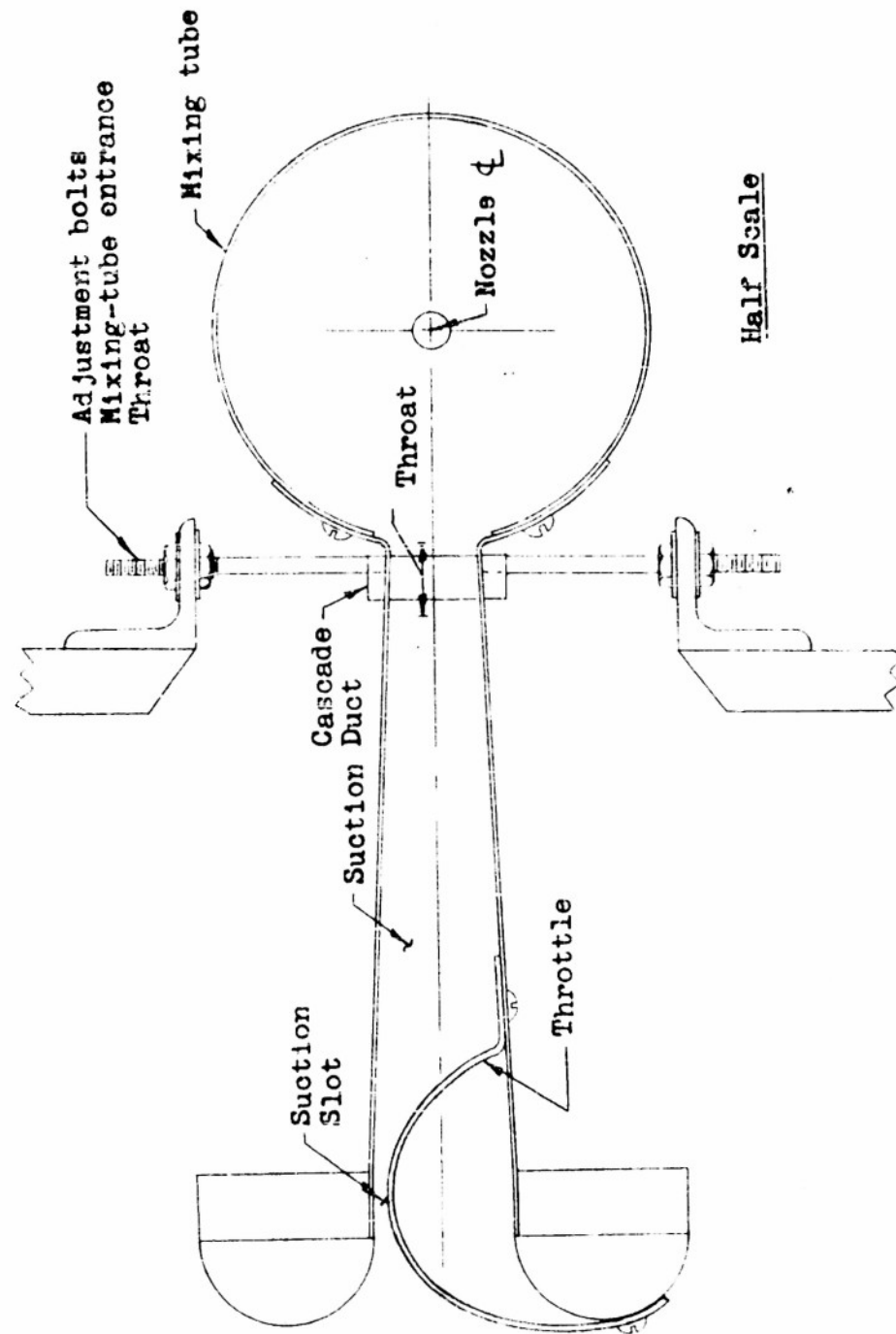


Figure 2.- Cross section of SICA-1 jet-pump at nozzle exit.

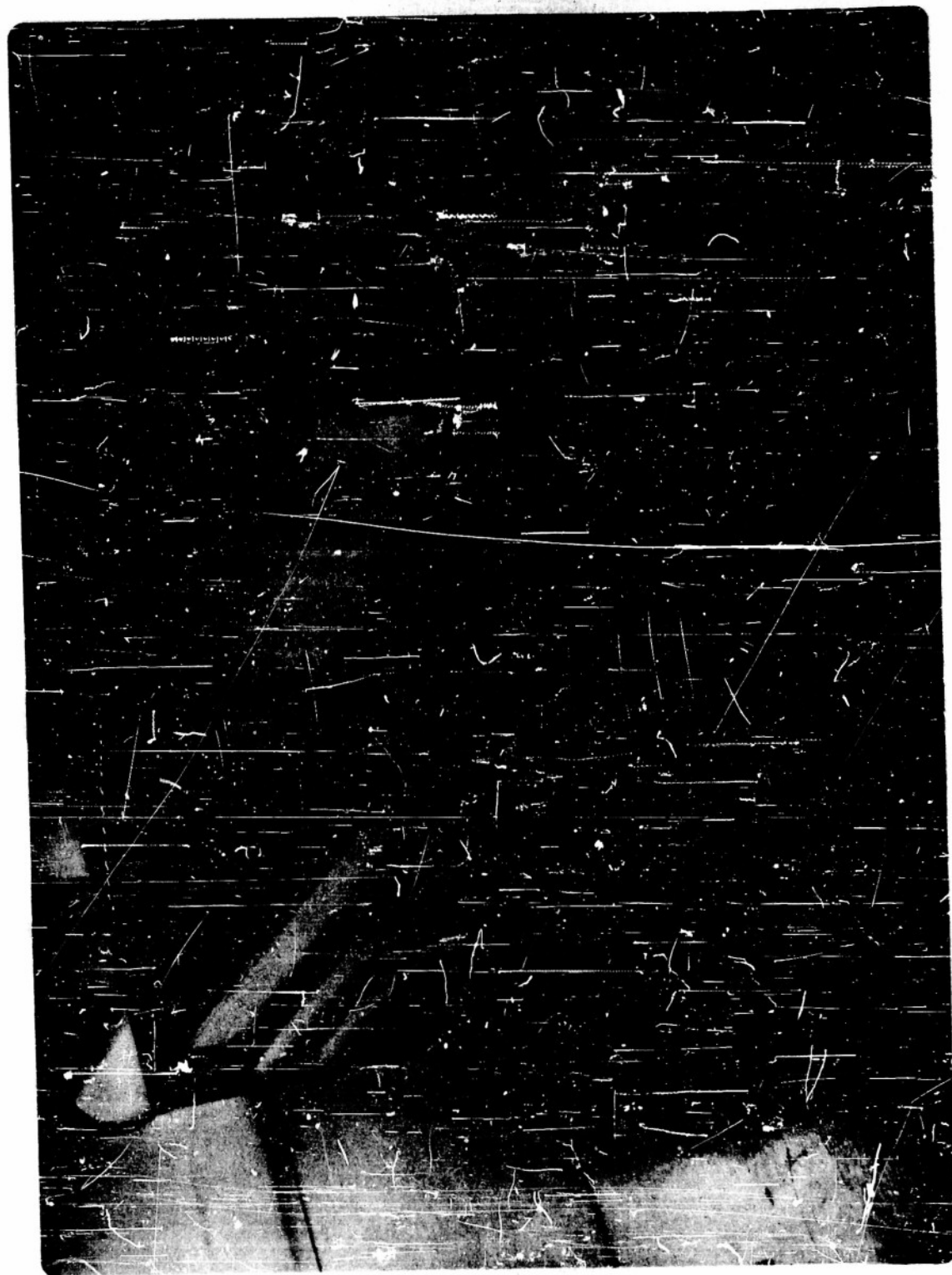


Figure 3.- Side-inlet, steam jet pump with an inboard nozzle.



Figure 4.- Arrangement of mixing-tube pressure taps and throat-adjustment bolts.

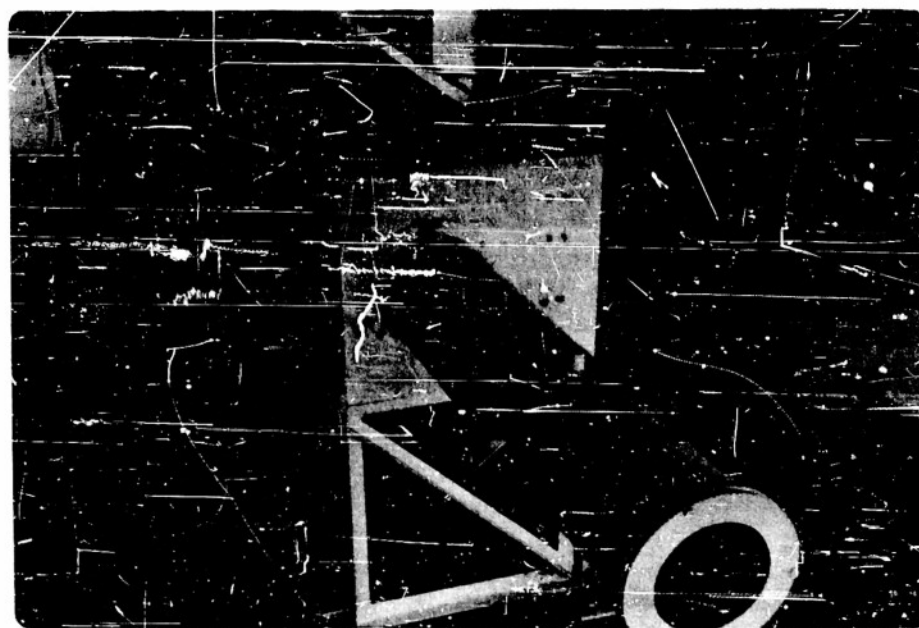


Figure 5.- Exit orifice installation.

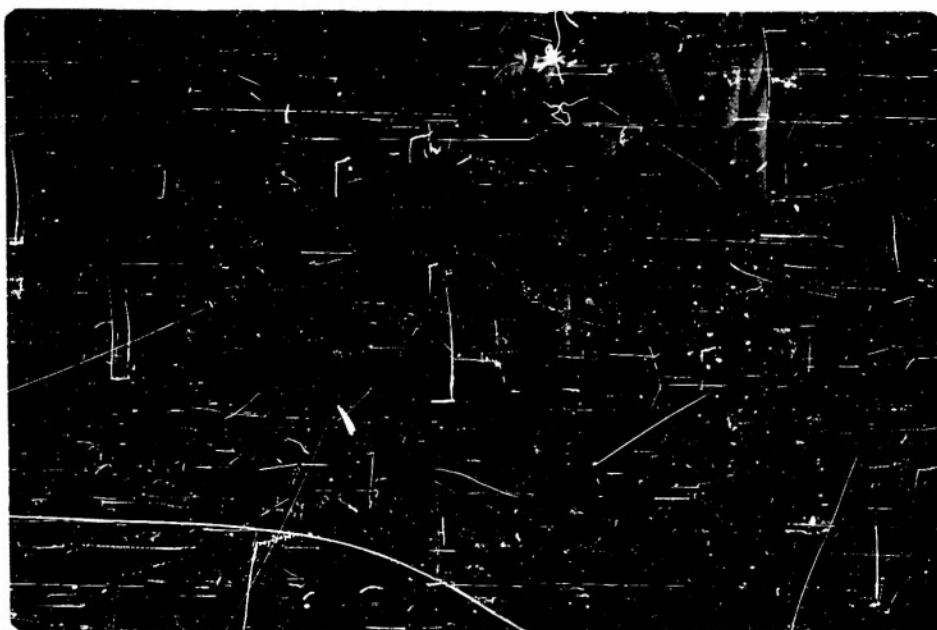


Figure 6.- Arrangement of mixing-tube static pressure taps.



Figure 7.- Arrangement of suction-slot pressure taps.

on right.





Figure 8.- Suction slot, static-pressure taps, and cascaded mixing-tube throat.

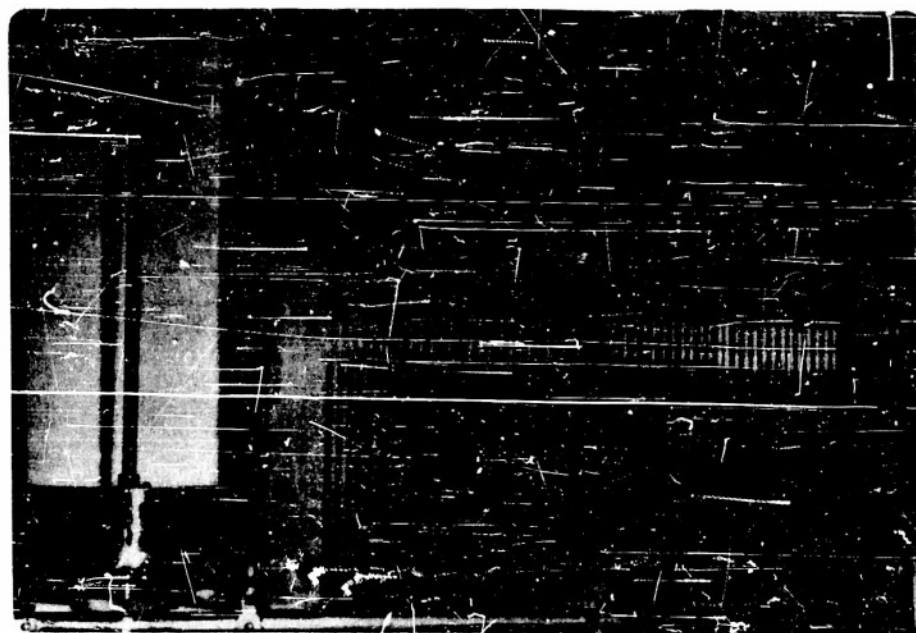


Figure 9.- Multitube manometer with static pressures of suction slot on left and mixing-tube throat on right.

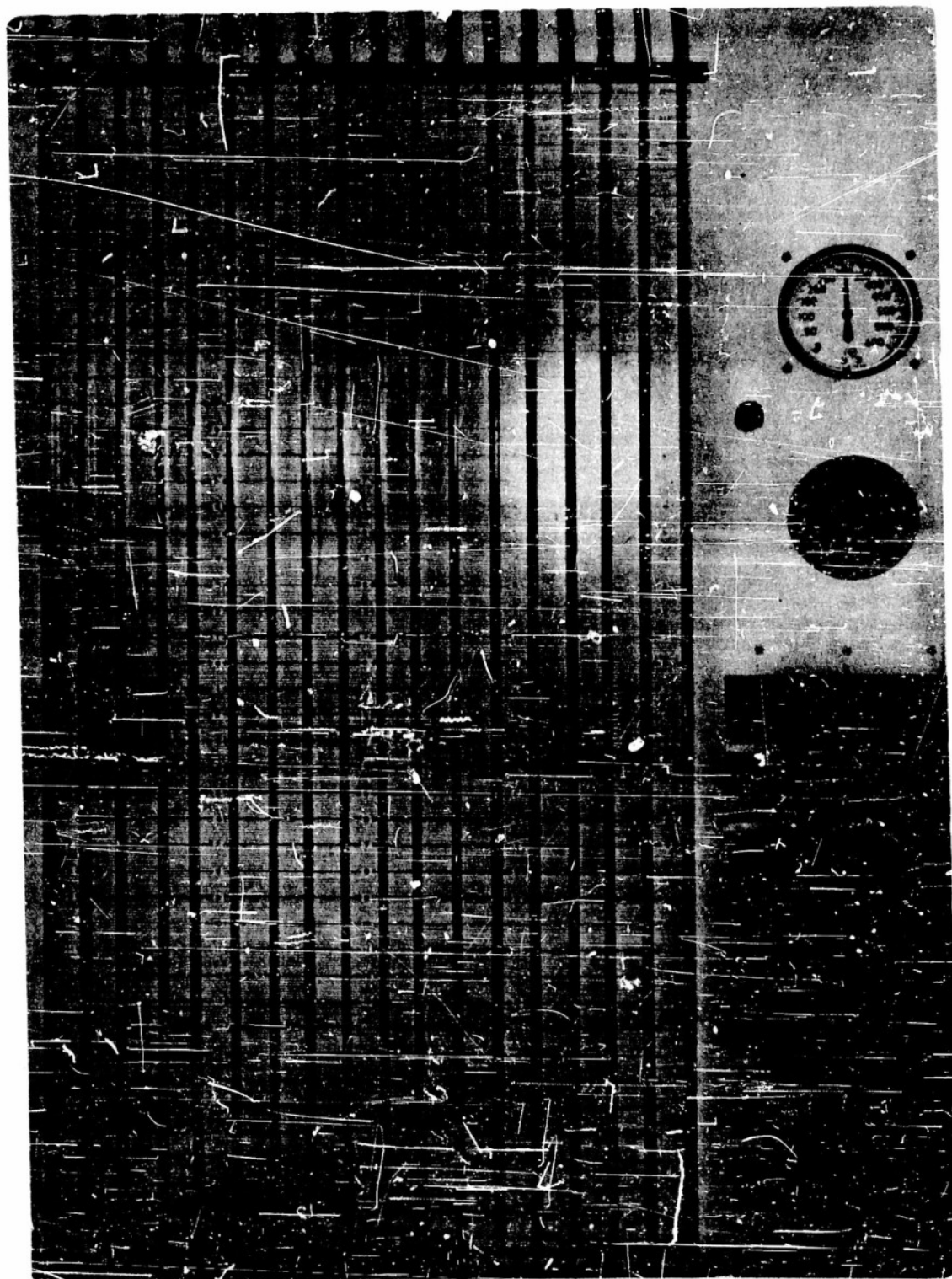


Figure 10.- Multitube manometer with mixing-tube static pressures on right and inboard suction-slot static pressures on left.

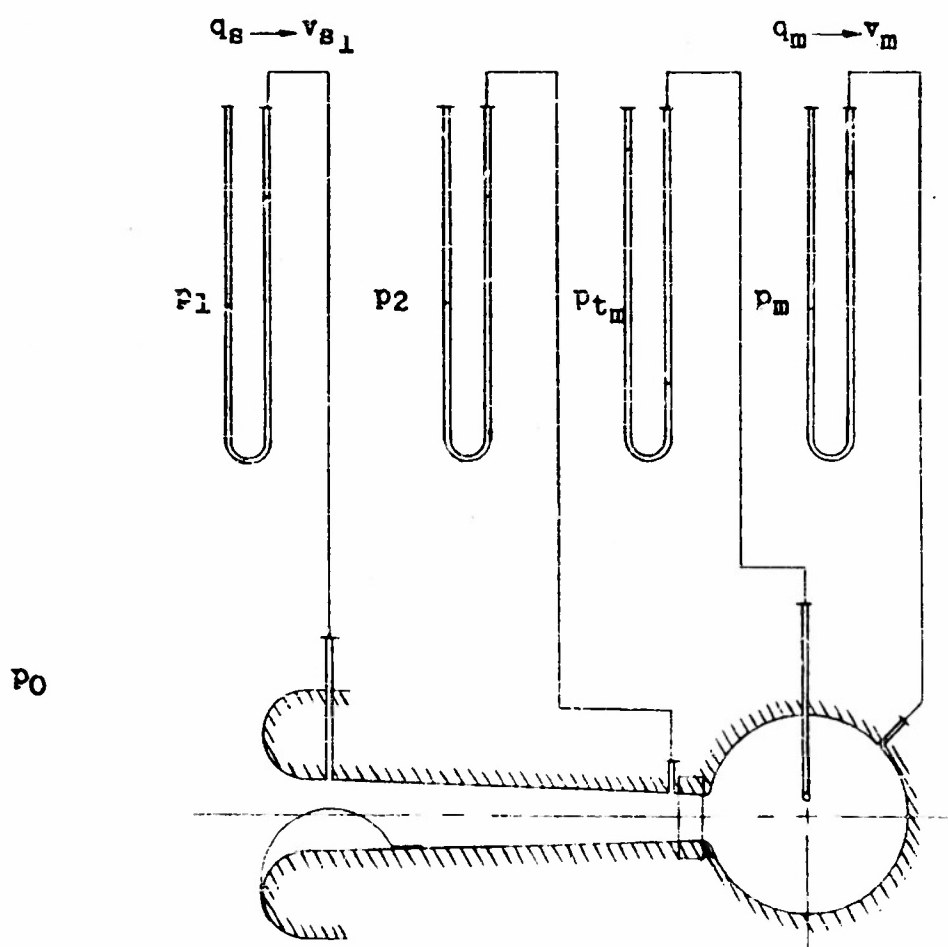
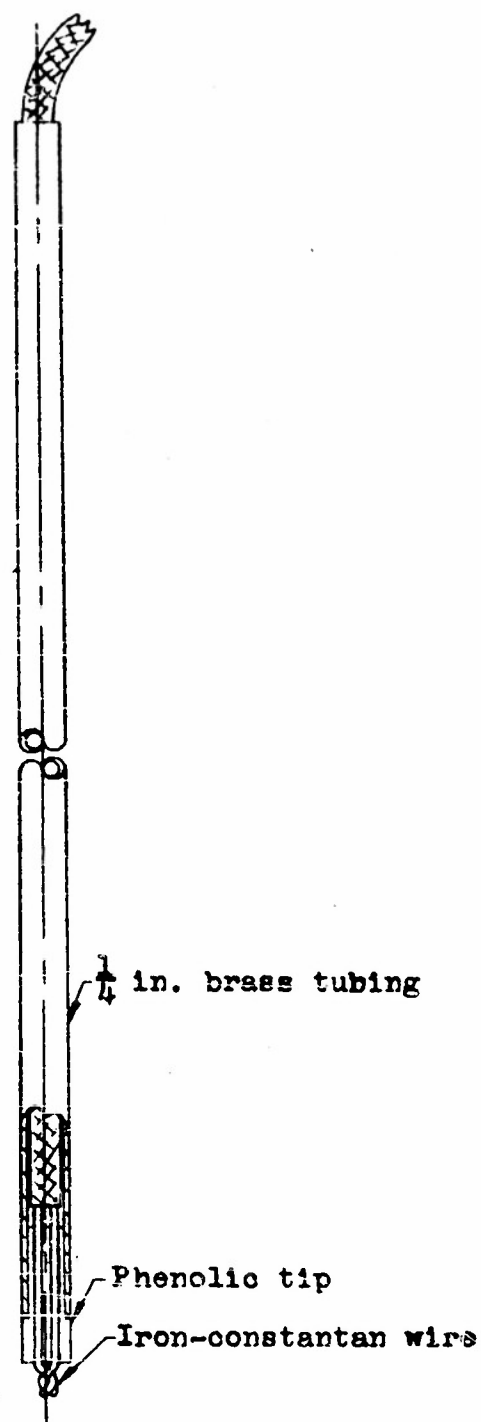


Figure 11.- Instrumentation schematic



Full Scale

Figure 12.- Mixing-tube temperature survey probe

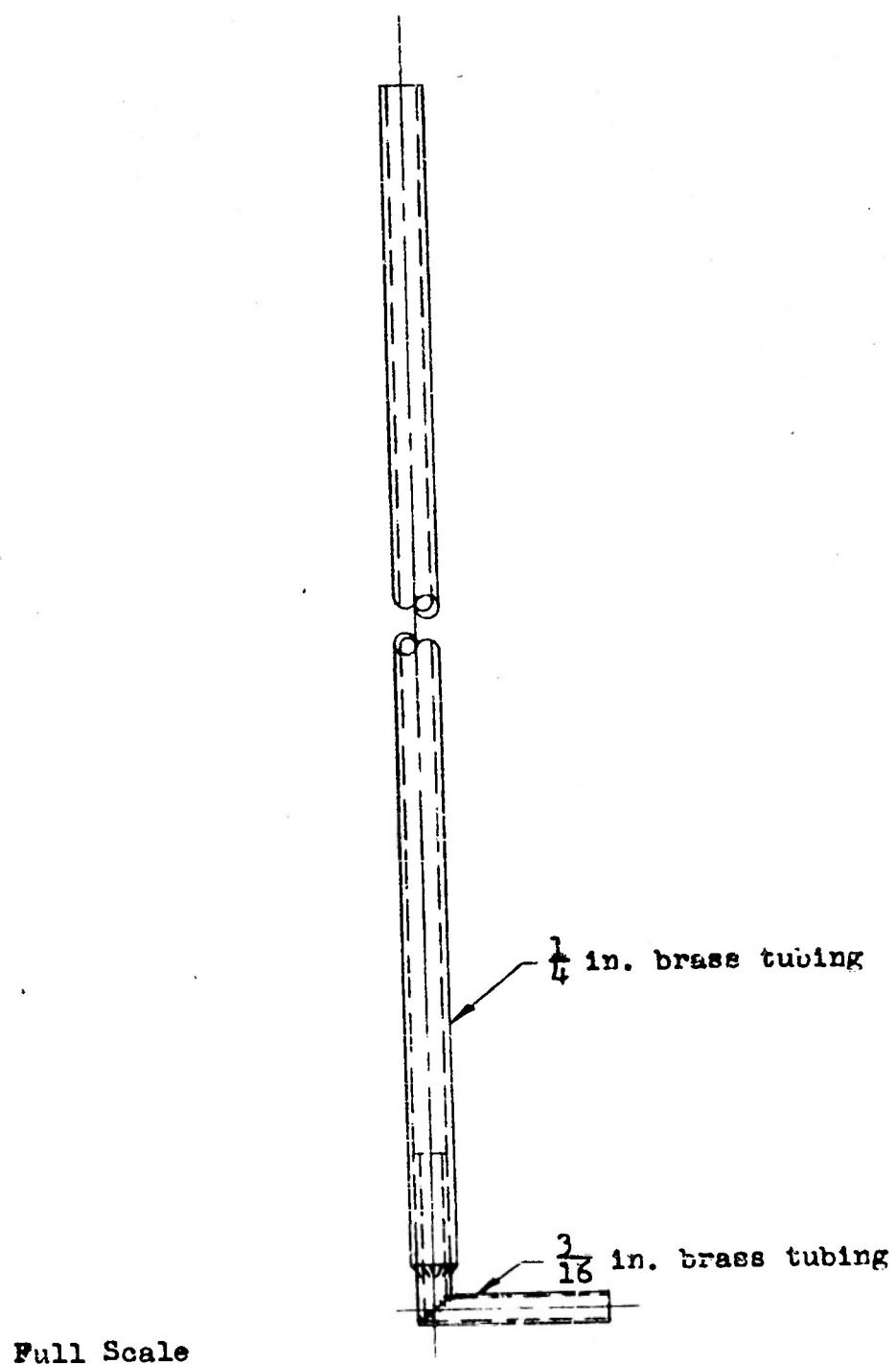


Figure 13.- Mixing-tube total-pressure survey probe.



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VARIATION OF  
PRESSURE RATIO  
WITH MASS RATIO  
SIDA-1 JET PUMP

$\bigcirc$   $\rho_2$  VARIABLE  
 $\bigcirc$   $\rho_2$  CONSTANT

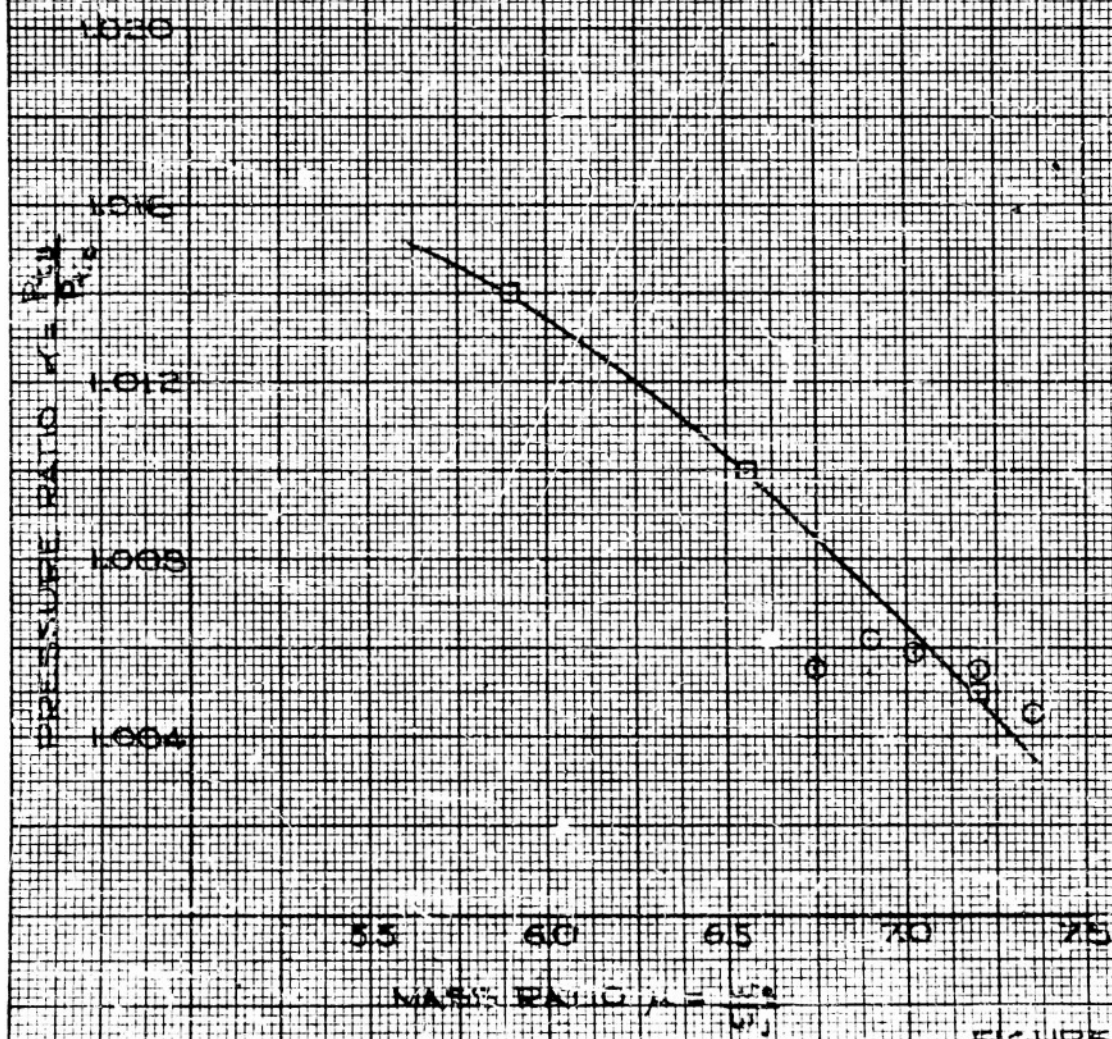


FIGURE 14  
APR 3-9-54

K&E  
KEOLAR & EGGERS CO.  
10 X 10 TO THE 1/2 INCH  
SERIES 871  
300-11.

UNIVERSITY OF WICHITA  
SCHOOL OF ENGINEERING

# VARIATION OF EFFICIENCY WITH MASS RATIO

STEAM TEST PUMP  
O  $\eta$  VARIABLE  
□  $\eta$  CONSTANT

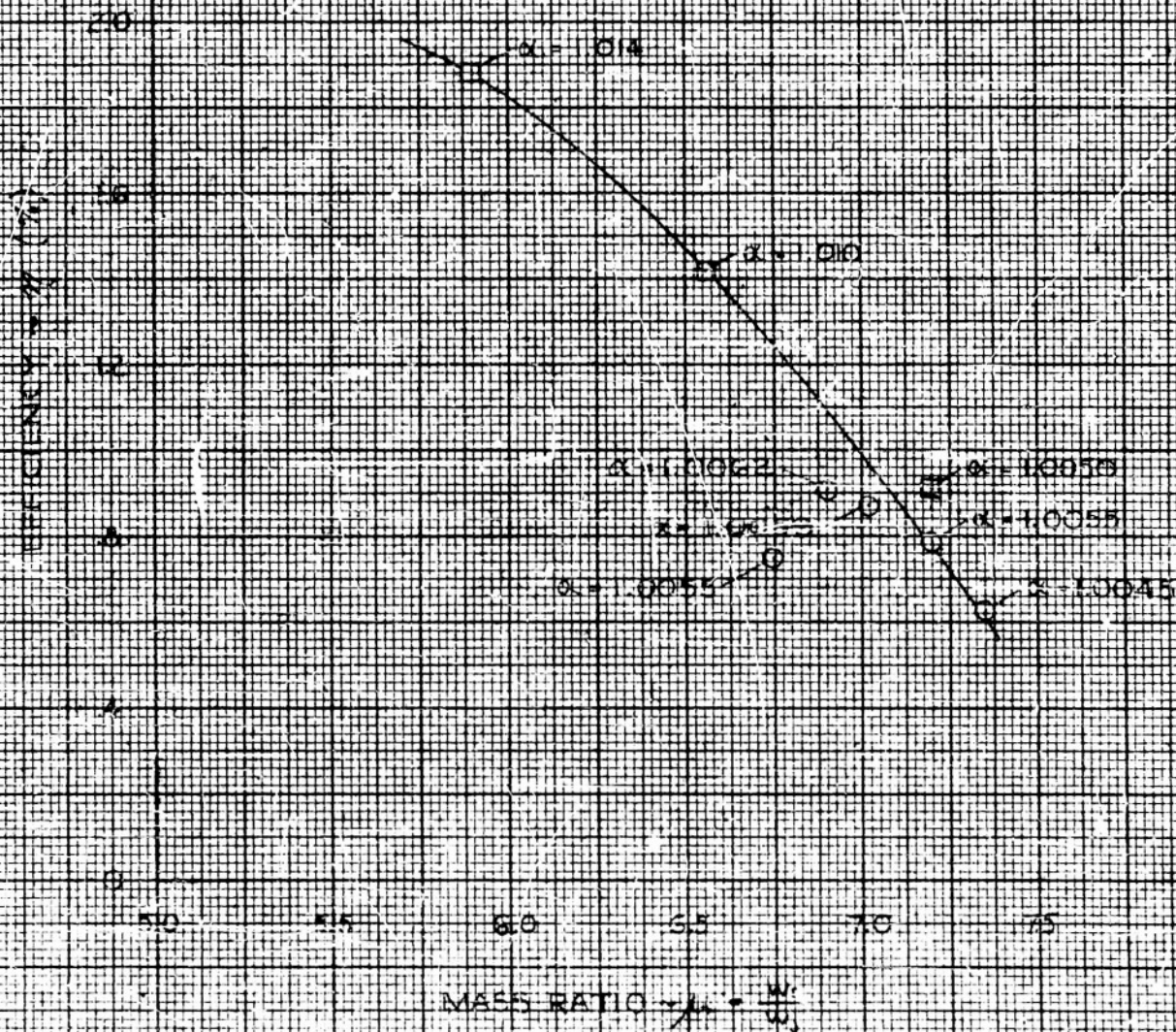


FIGURE 3

C. BECK, S. W. SA

K.M.

RESEARCH ENGINEERING CO.  
10 X 10.1" THE X INCH

328-11



K&E  
KENDALL & ESCOFFER CO.  
10 X 10 TO THE 1/2 INCH  
MILB R.T.V.  
320-11

UNIVERSITY OF WISCONSIN  
SCHOOL OF ENGINEERING

DISTRIBUTION OF  
AVAILABLE ENERGY  
EFFICIENCY

0.0001 STEADY STATE

AVAILABLE ENERGY EFFICIENCY  $\eta = \frac{P}{P_0}$

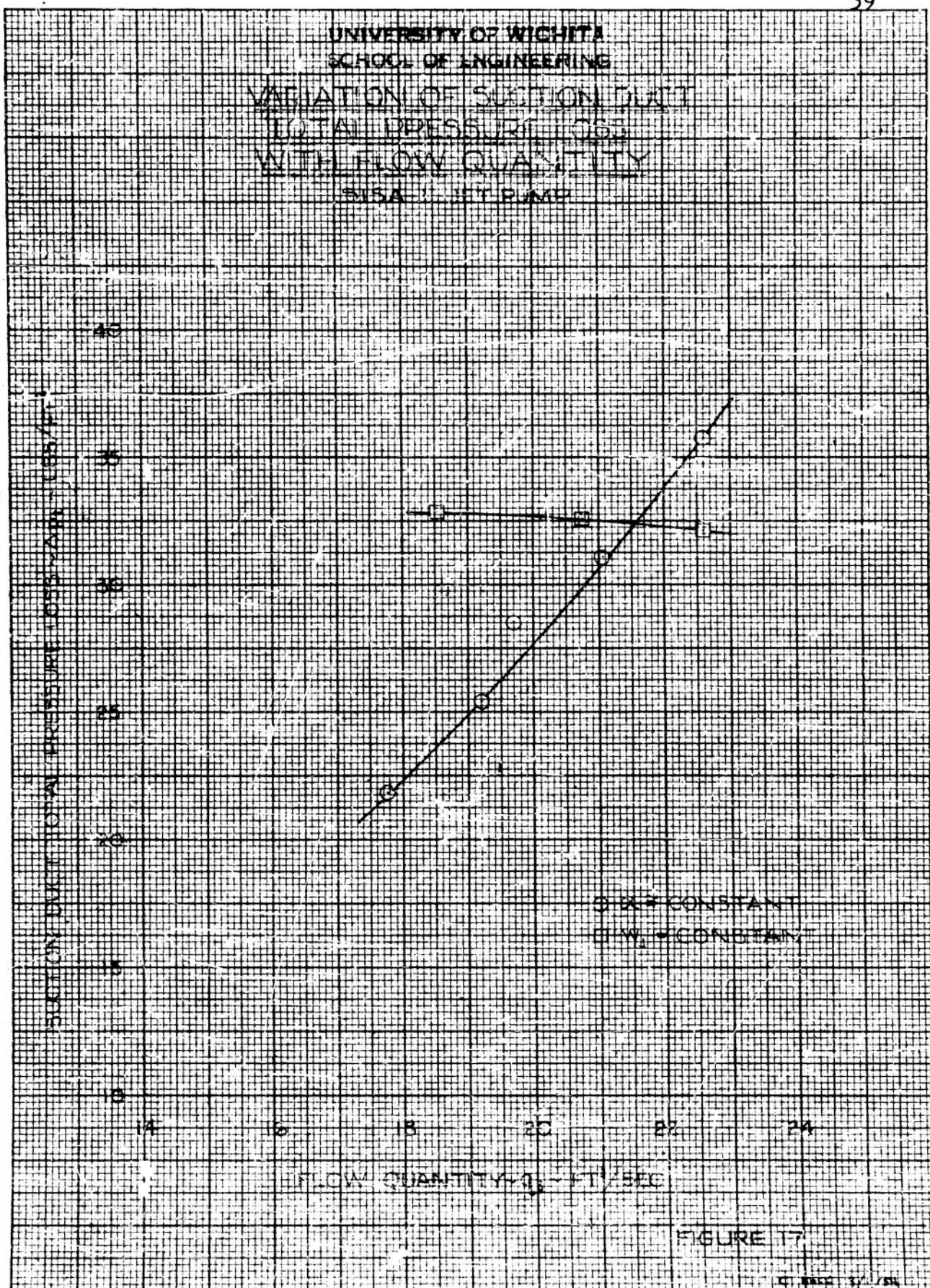
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0 16.5 17.0 17.5 18.0 18.5 19.0 19.5 20.0 20.5 21.0 21.5 22.0 22.5 23.0 23.5 24.0 24.5 25.0 25.5 26.0 26.5 27.0 27.5 28.0 28.5 29.0 29.5 30.0 30.5 31.0 31.5 32.0 32.5 33.0 33.5 34.0 34.5 35.0 35.5 36.0 36.5 37.0 37.5 38.0 38.5 39.0 39.5 40.0 40.5 41.0 41.5 42.0 42.5 43.0 43.5 44.0 44.5 45.0 45.5 46.0 46.5 47.0 47.5 48.0 48.5 49.0 49.5 50.0 50.5 51.0 51.5 52.0 52.5 53.0 53.5 54.0 54.5 55.0 55.5 56.0 56.5 57.0 57.5 58.0 58.5 59.0 59.5 60.0 60.5 61.0 61.5 62.0 62.5 63.0 63.5 64.0 64.5 65.0 65.5 66.0 66.5 67.0 67.5 68.0 68.5 69.0 69.5 70.0 70.5 71.0 71.5 72.0 72.5 73.0 73.5 74.0 74.5 75.0 75.5 76.0 76.5 77.0 77.5 78.0 78.5 79.0 79.5 80.0 80.5 81.0 81.5 82.0 82.5 83.0 83.5 84.0 84.5 85.0 85.5 86.0 86.5 87.0 87.5 88.0 88.5 89.0 89.5 90.0 90.5 91.0 91.5 92.0 92.5 93.0 93.5 94.0 94.5 95.0 95.5 96.0 96.5 97.0 97.5 98.0 98.5 99.0 99.5 100.0

MARKING TUBE LENGTH IN FEET

FIGURE 16

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SCHOOL OF ENGINEERING

VARIATION OF SUCTION DUCT  
TOTAL PRESSURE LOSS  
WITH FLOW QUANTITY  
SUSA 1/2 HP PUMP





SCHOOL OF ENGINEERING  
UNIVERSITY OF MICHIGAN

# EFFECT OF JET PRESSURE VARIATION ON INJECTION SLOT FLOW

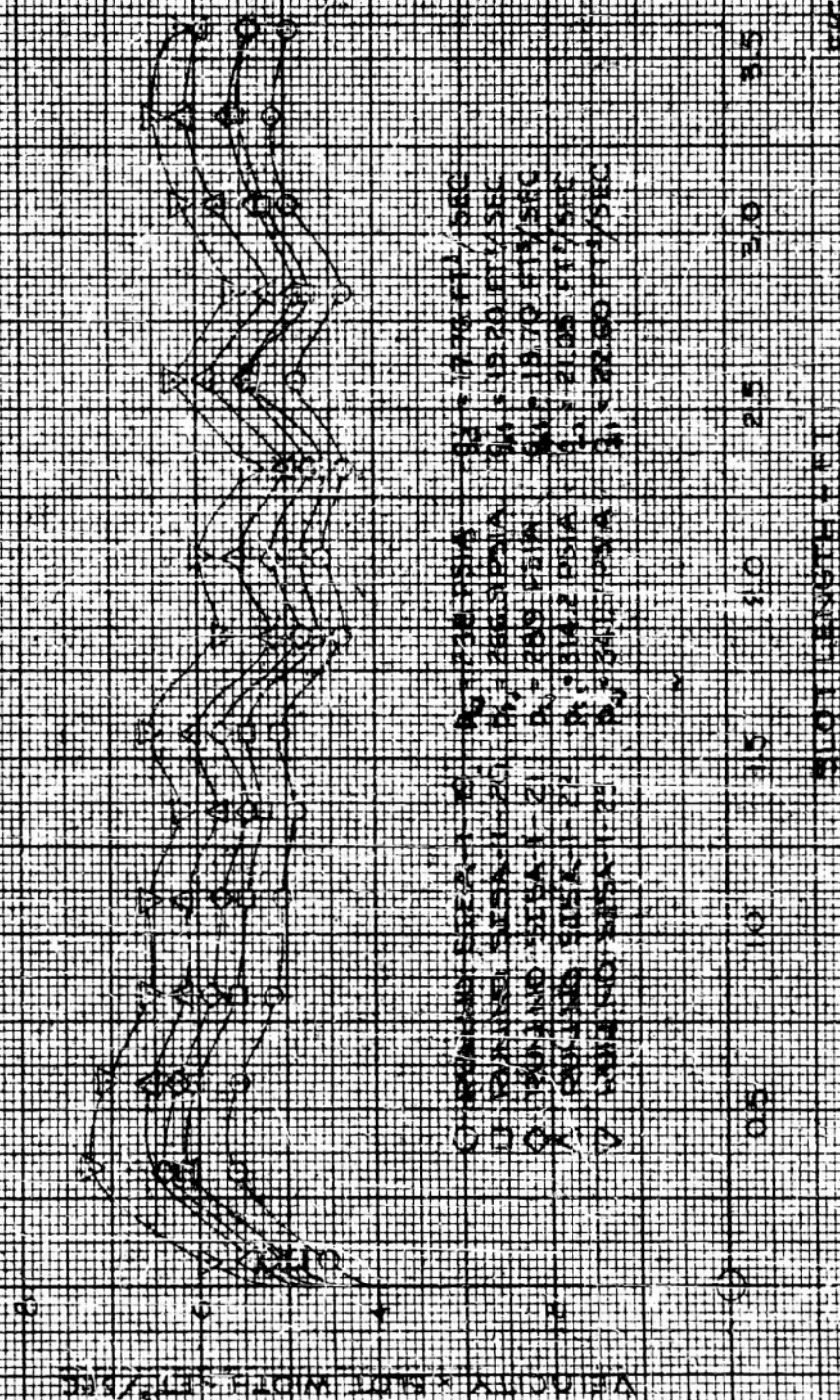
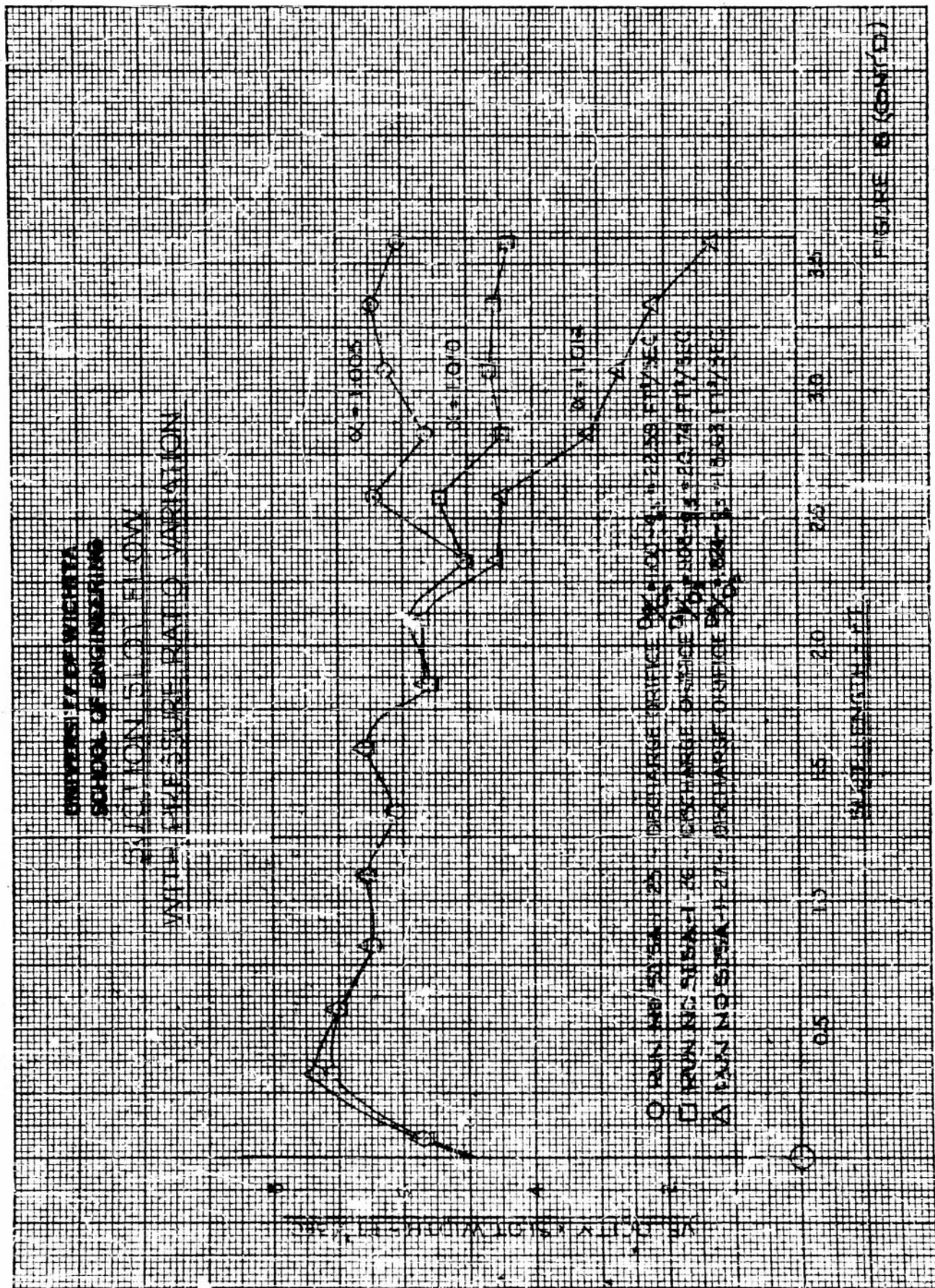


FIGURE 1B





K&amp;E KENNEDY &amp; ESBEL CO.

MADE IN U.S.A.  
329 11UNIVERSITY OF WICHITA  
SCHOOL OF ENGINEERING

## SECTION SLOT FLOW

WITH PRESSURE RATIO VARIATION

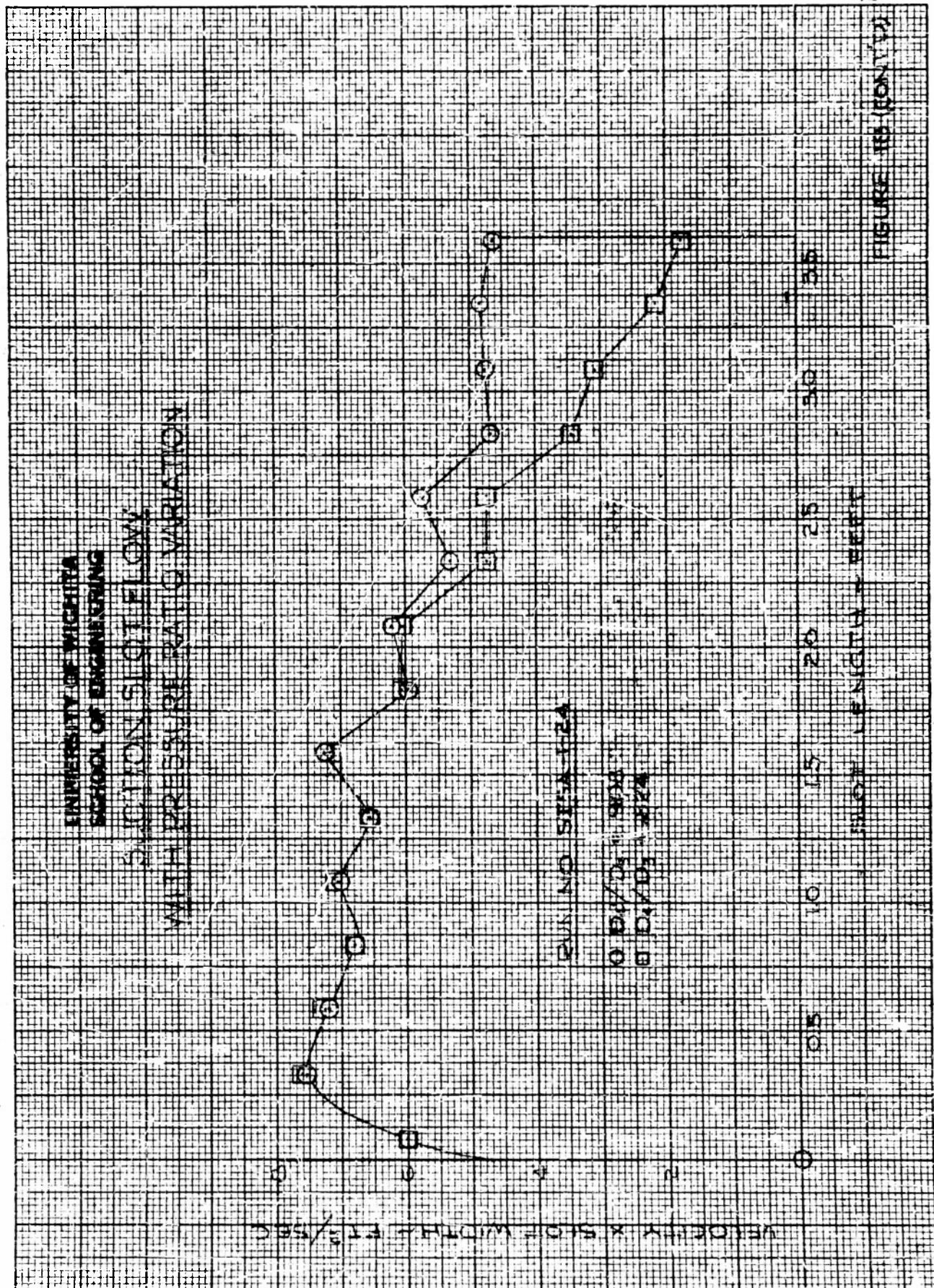
VELOCITY X SLOT WIDTH =  $FT^2/SEC$ 

P/N NO. 511-22

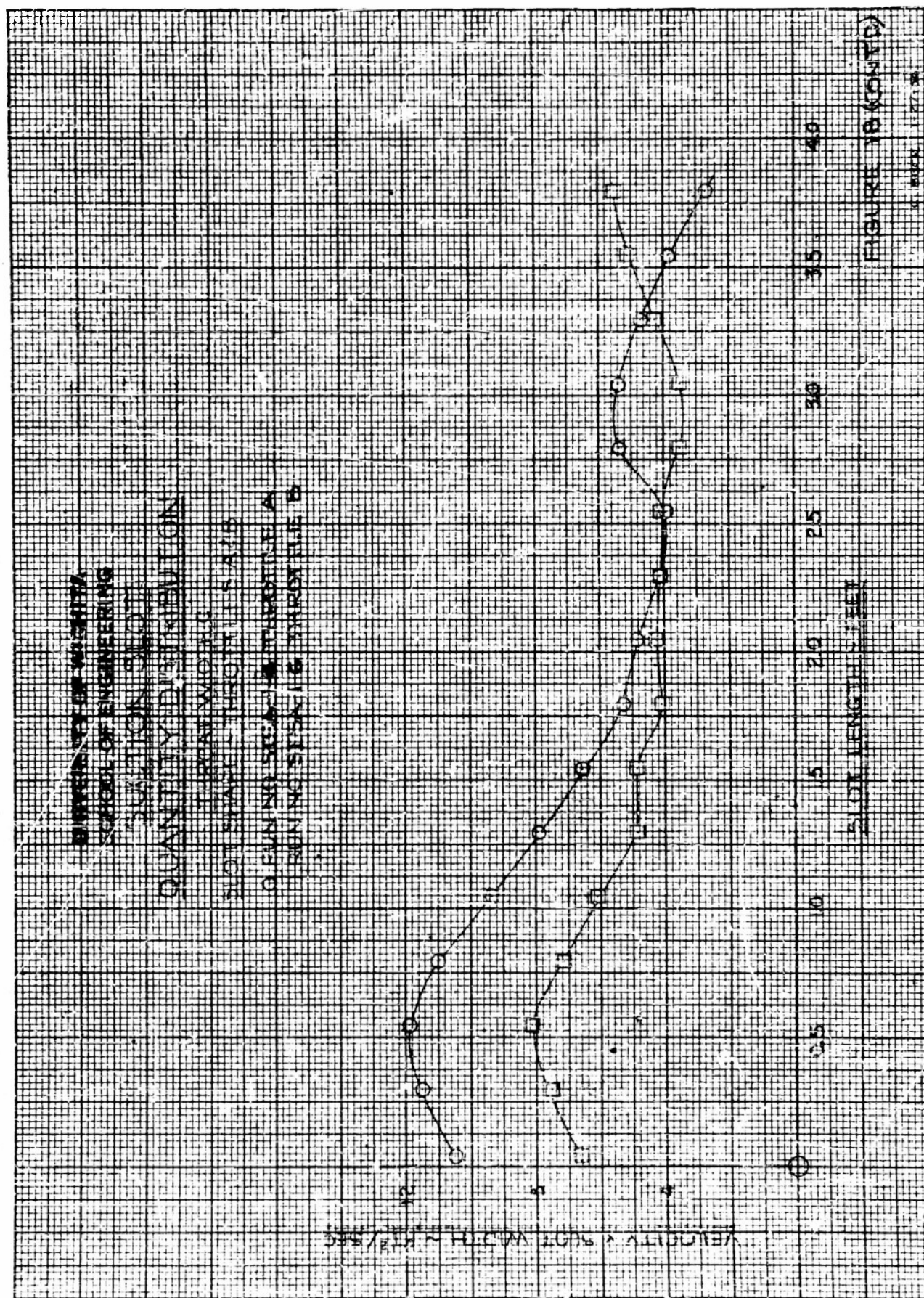
WATER 50°F/10°C  
PRESS. 100 PSI

FLOW LENGTH - FEET

FIGURE 1B (CONT'D)







# UNIFORMITY OF DISTRIBUTION

ANALYSIS OF ENGINEERING DATA

## SUGGESTION 3101 QUALITY DISTRIBUTION

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- 100. RUNNING THROUGH MIXING

VELOCITY - 5.0 FT/SEC



VELOCITY - 5.0 FT/SEC

FIGURE 1800-11

44



UNIVERSITY OF MICHIGAN  
ENGINEERING SCHOOL

# QUANTITY DISTRIBUTION TORSION

DISCUSSION OF THEORETICAL  
TORSION WITH 1.0

DISCUSSION OF THEORETICAL  
TORSION WITH 1.0

VELOCITY X SLOT WIDTH - FT./SEC

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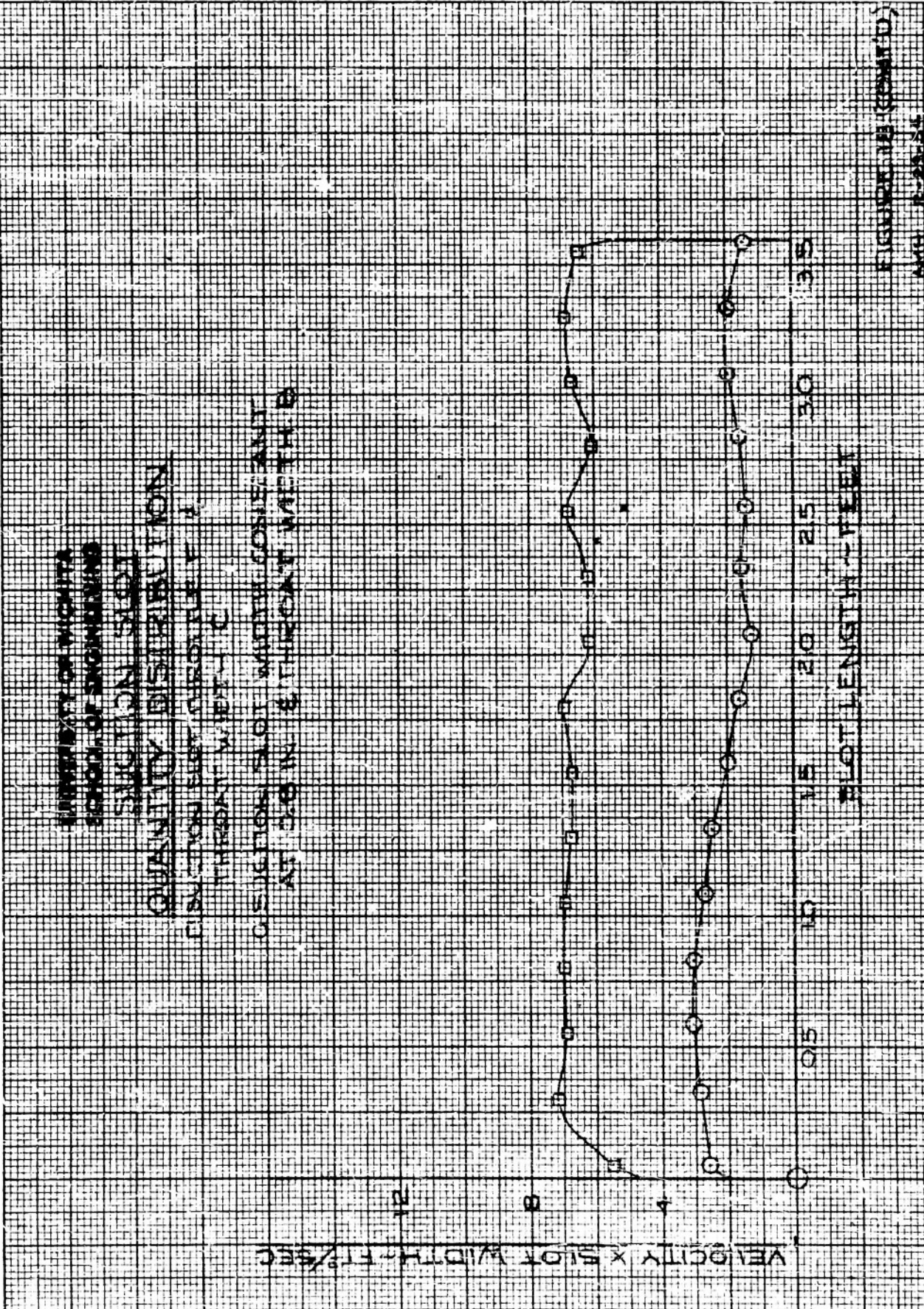
40

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PLOT LENGTH - FEET

FIGURE 11 (CONT'D)

APR 1954



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SCHOOL OF ENGINEERING  
EFFECT OF CASCADES  
ON SUCTION SLOT  
QUANTITY DISTRIBUTION



FIGURE 16 (CONT'D)

U. S. NAVY



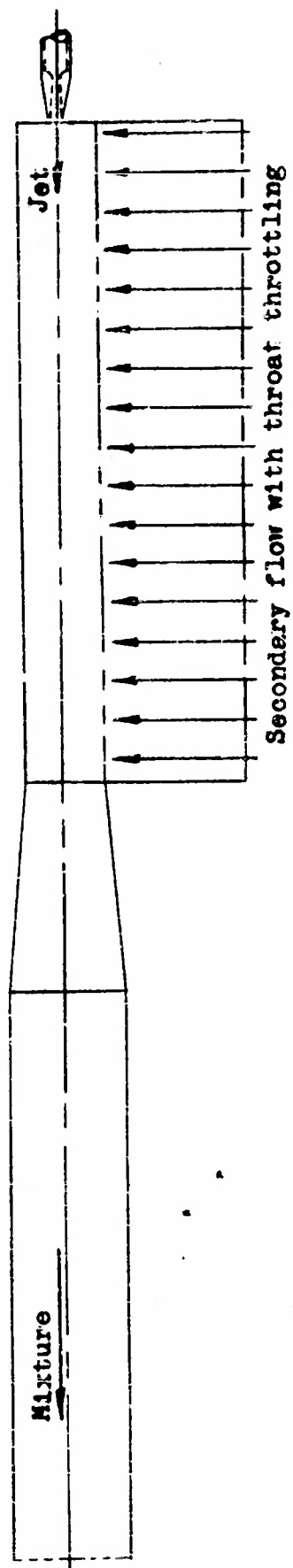
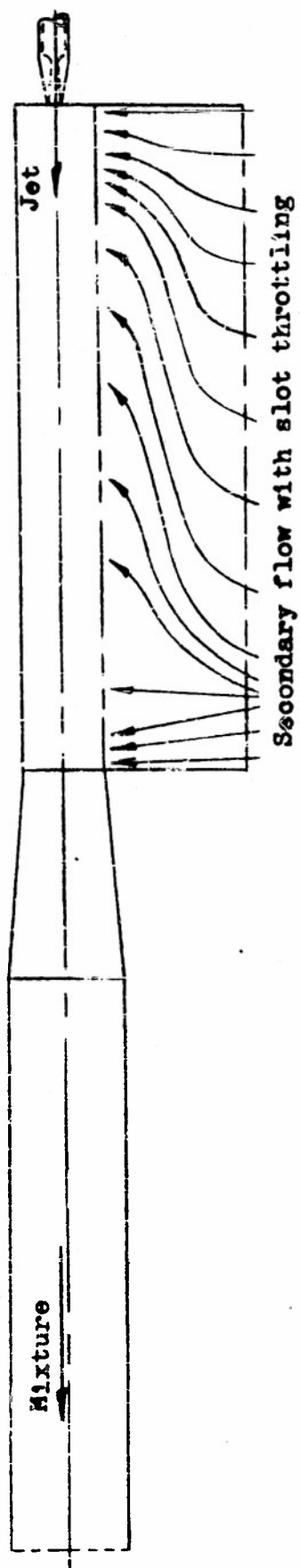
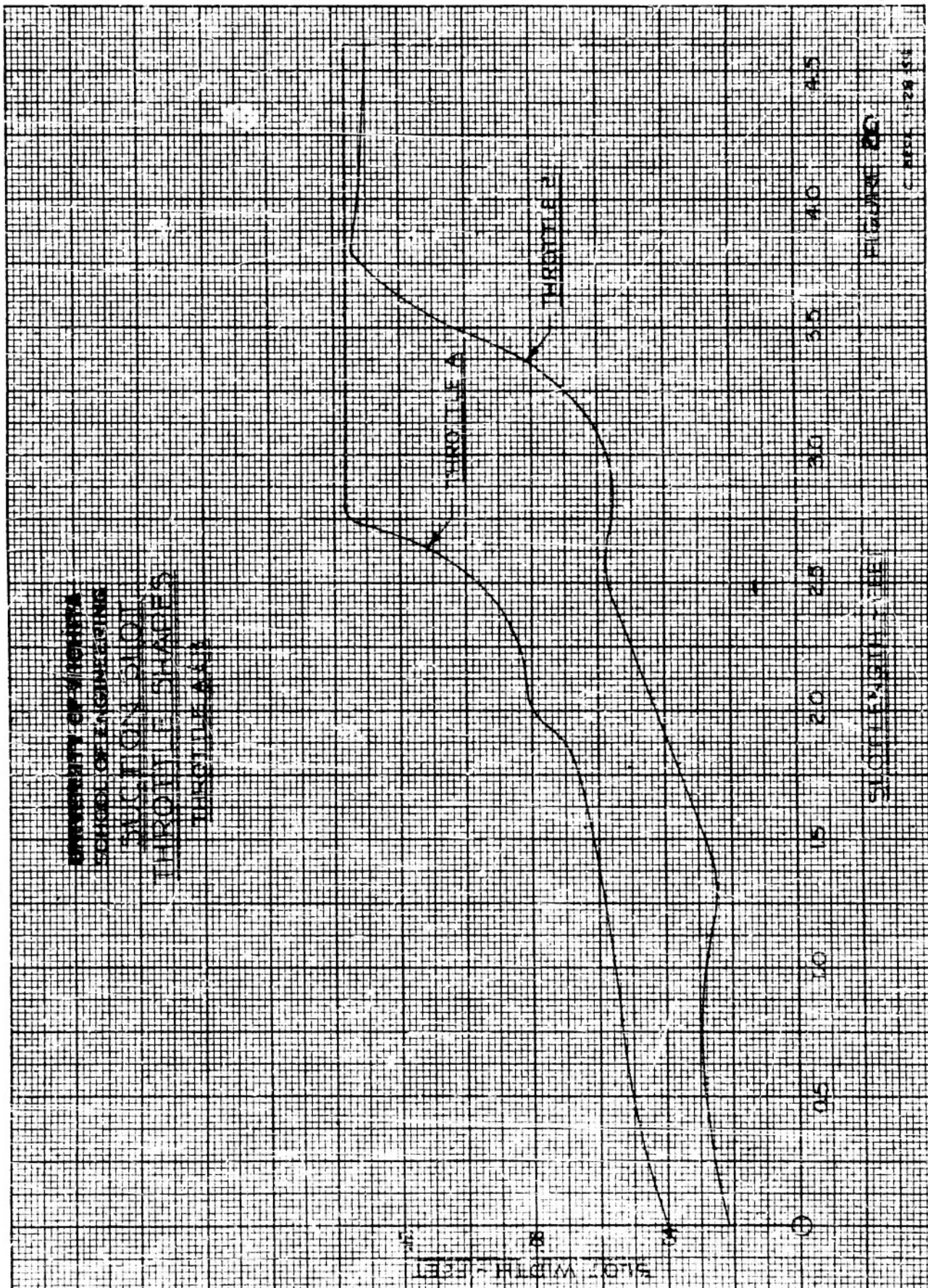


Figure 19. Suction-duct flow pattern with slot and throat throttling.







**DESIGN OF MIXING TUBE**

DESIGN OF MIXING TUBE  
MIXING TUBE ENTRANCE  
CHITUM (NORMAL)  
TUBES ARE ALL

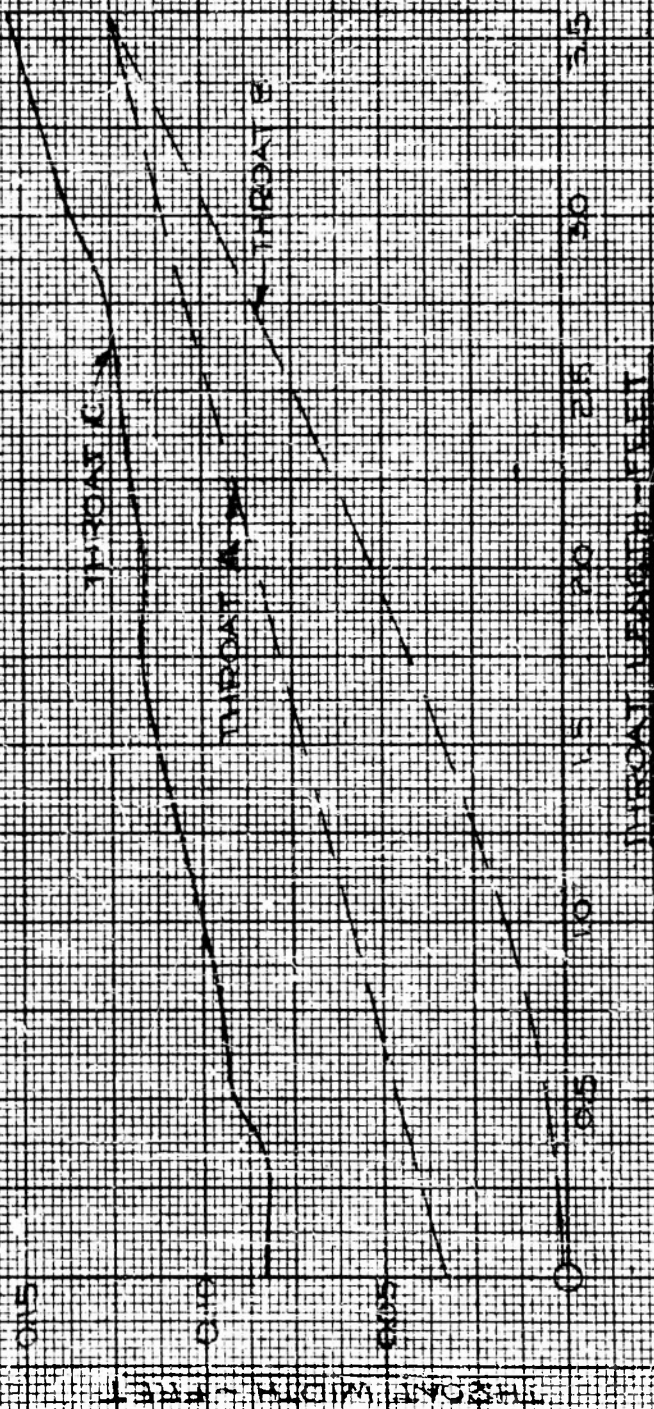


FIGURE 21

REVISION 2-3-54

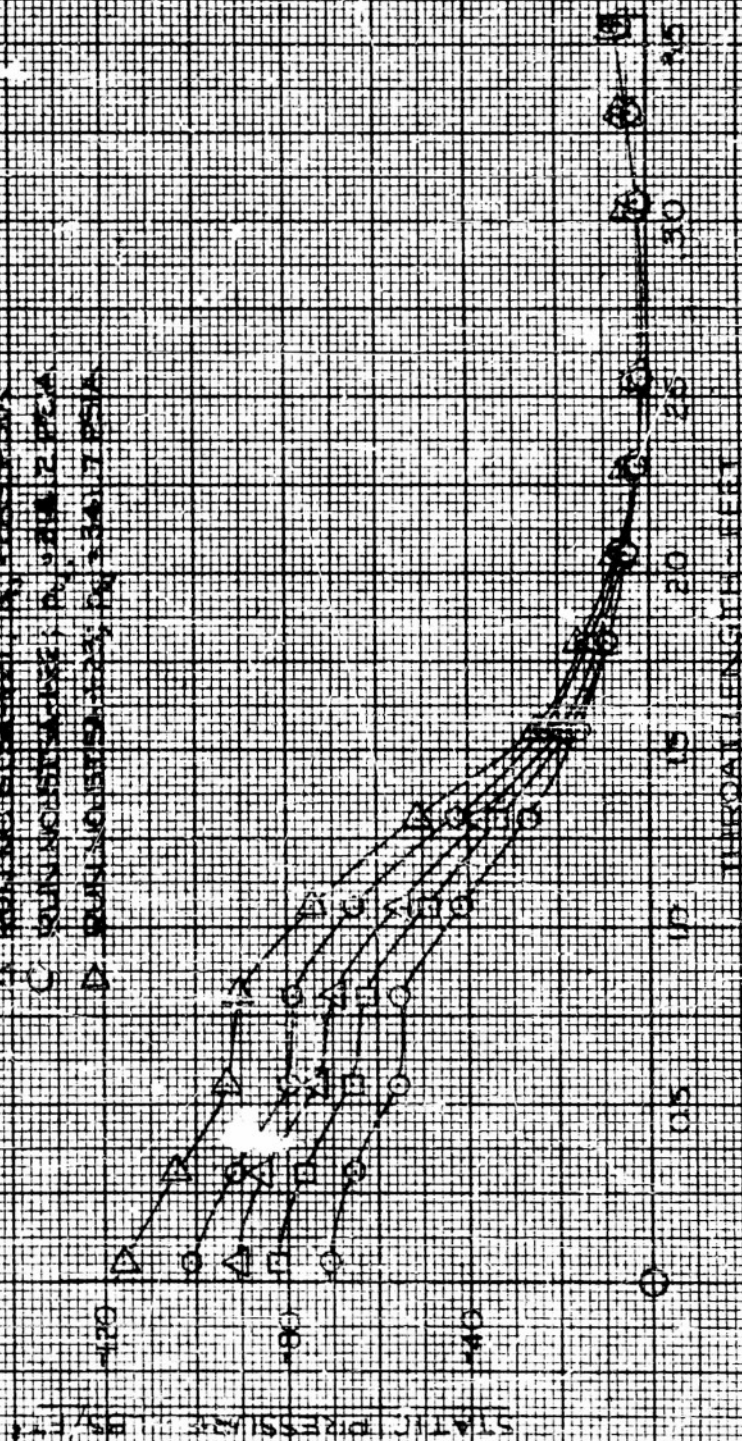


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SCHOOL OF ENGINEERING

EFFECT OF JET PRESSURE  
VARIATION ON THERMAL  
STABILITY OF PIPE

STABILITY OF PIPE

- RUN NO. 100-100,  $P_0 = 200$  PSIA
- RUN NO. 100-100,  $P_0 = 200$  PSIA
- △ RUN NO. 100-100,  $P_0 = 200$  PSIA
- RUN NO. 100-100,  $P_0 = 200$  PSIA
- △ RUN NO. 100-100,  $P_0 = 200$  PSIA

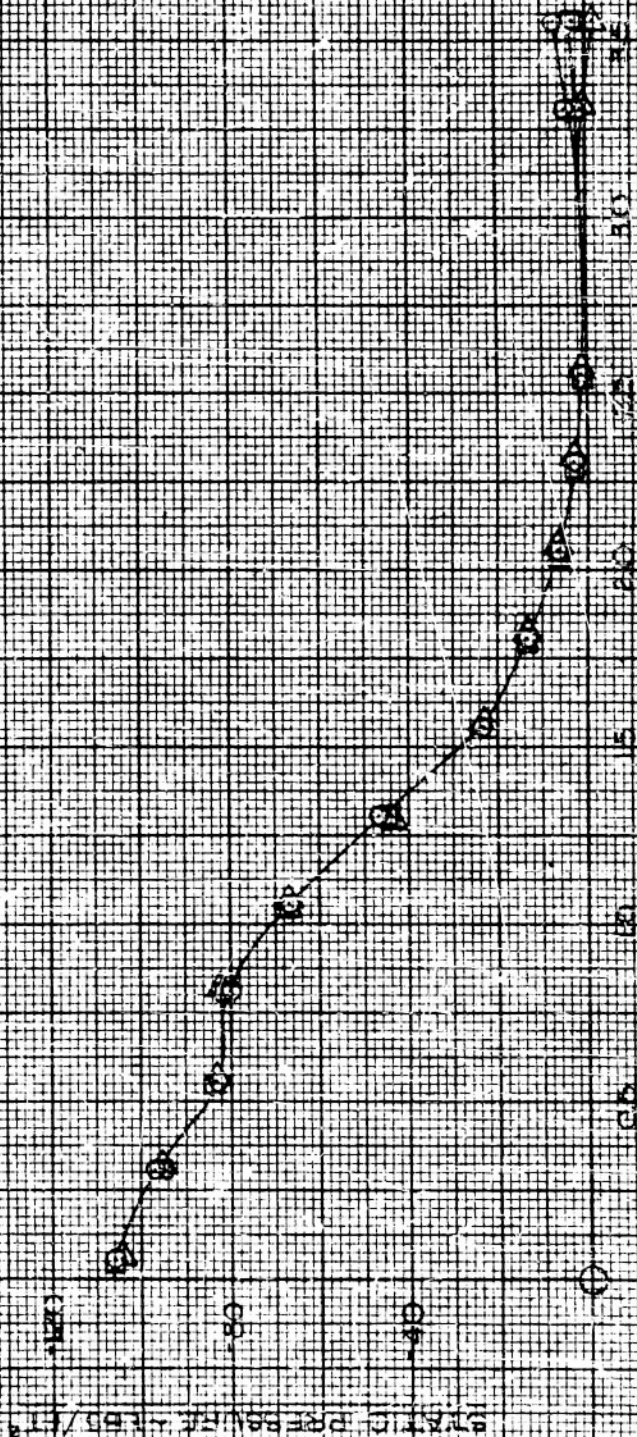




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SCHOOL OF ENGINEERING

EFFECT OF PRESSURE RATIO  
VARIATION ON THROAT  
STATIC PRESSURE

1. RUN NO. 152425148005  
2. RUN NO. 152425148005  
3. RUN NO. 152425148005  
4. RUN NO. 152425148005



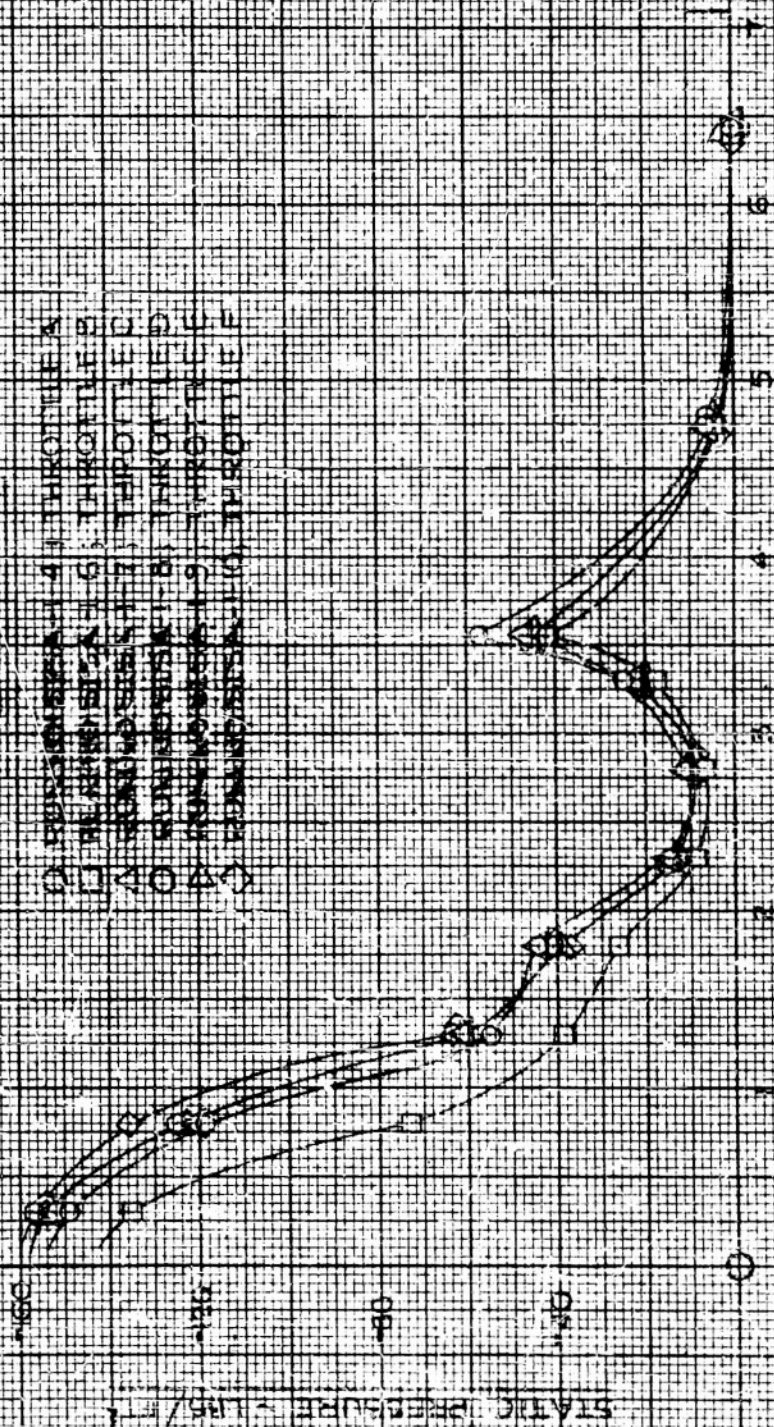




## EFFECT OF THROTTLE SHAFT POSITION ON THE ENGINE SPEED AND FUEL CONSUMPTION OF A DIESEL ENGINE

THIRTY-SEVEN

1. PROPOSAL 2. THROTTLE 3. THROTTLE 4. THROTTLE 5. THROTTLE 6. THROTTLE 7. THROTTLE 8. THROTTLE 9. THROTTLE 10. THROTTLE 11. THROTTLE 12. THROTTLE 13. THROTTLE 14. THROTTLE 15. THROTTLE 16. THROTTLE 17. THROTTLE 18. THROTTLE 19. THROTTLE 20. THROTTLE 21. THROTTLE 22. THROTTLE 23. THROTTLE 24. THROTTLE 25. THROTTLE 26. THROTTLE 27. THROTTLE 28. THROTTLE 29. THROTTLE 30. THROTTLE 31. THROTTLE 32. THROTTLE 33. THROTTLE 34. THROTTLE 35. THROTTLE 36. THROTTLE 37. THROTTLE 38. THROTTLE 39. THROTTLE 40. THROTTLE 41. THROTTLE 42. THROTTLE 43. THROTTLE 44. THROTTLE 45. THROTTLE 46. THROTTLE 47. THROTTLE 48. THROTTLE 49. THROTTLE 50. THROTTLE 51. THROTTLE 52. THROTTLE 53. THROTTLE 54. THROTTLE 55. THROTTLE 56. THROTTLE 57. THROTTLE 58. THROTTLE 59. THROTTLE 60. THROTTLE 61. THROTTLE 62. THROTTLE 63. THROTTLE 64. THROTTLE 65. THROTTLE 66. THROTTLE 67. THROTTLE 68. THROTTLE 69. THROTTLE 70. THROTTLE 71. THROTTLE 72. THROTTLE 73. THROTTLE 74. THROTTLE 75. THROTTLE 76. THROTTLE 77. THROTTLE 78. THROTTLE 79. THROTTLE 80. THROTTLE 81. THROTTLE 82. THROTTLE 83. THROTTLE 84. THROTTLE 85. THROTTLE 86. THROTTLE 87. THROTTLE 88. THROTTLE 89. THROTTLE 90. THROTTLE 91. THROTTLE 92. THROTTLE 93. THROTTLE 94. THROTTLE 95. THROTTLE 96. THROTTLE 97. THROTTLE 98. THROTTLE 99. THROTTLE 100. THROTTLE



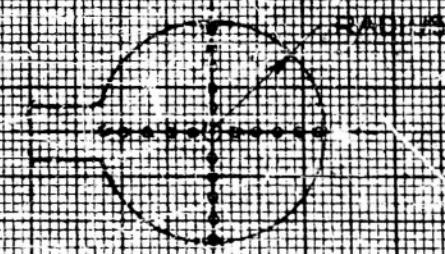
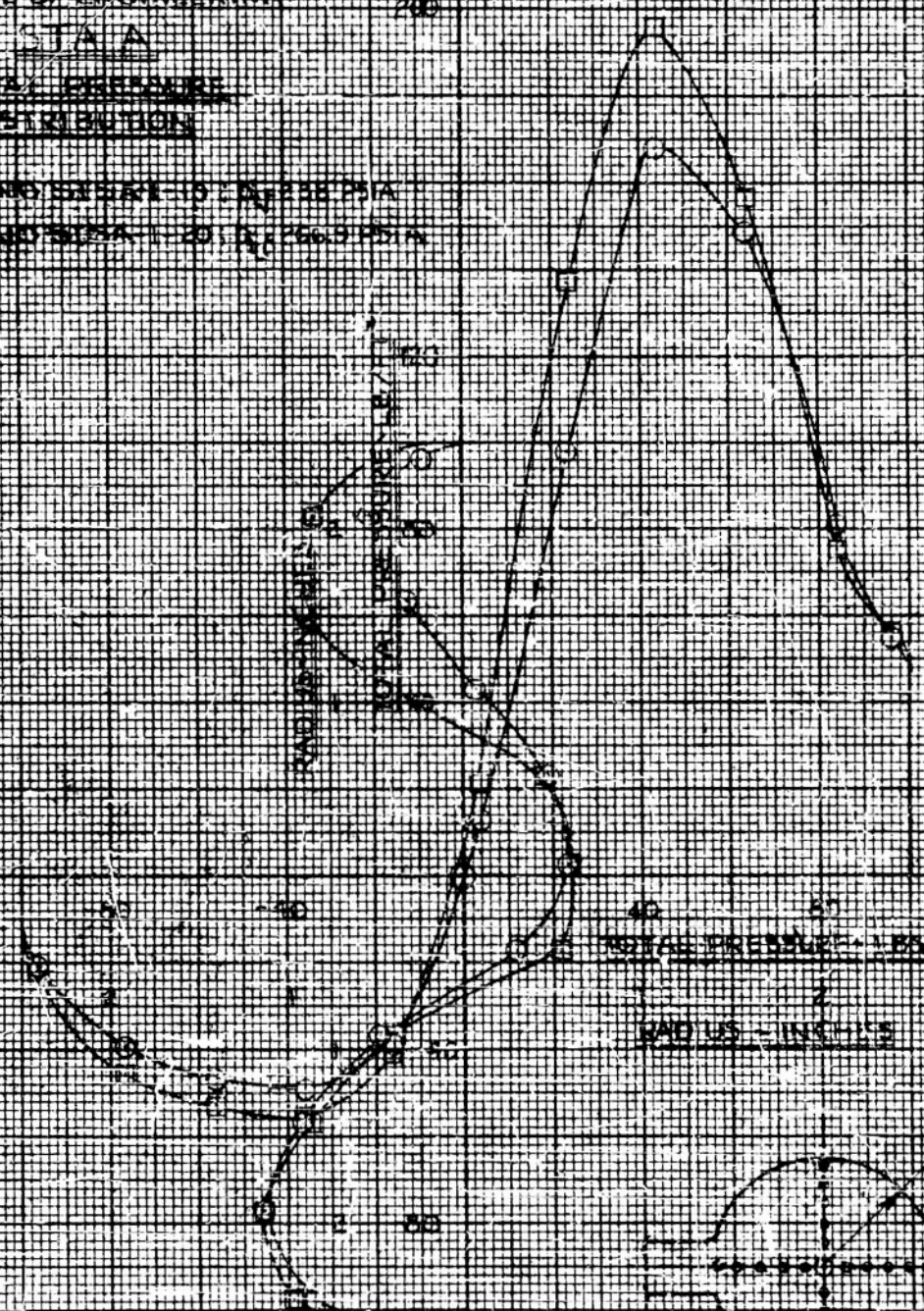
FF GUERE 23 (CONC'D)

6XKX119 TUBE; 300T; 11.500; 11.500; 11.500

UNIVERSITY OF MICHIGAN  
SCHOOL OF ENGINEERING

STAA  
TOTAL PRESSURE  
DISTRIBUTION

- TAP NO. 15 - 1.5 IN. DIA
- TAP NO. 16 - 2.0 IN. DIA



COPIED SURVEY  
POSITIONS  
(UPSTREAM VIEW)

FIGURE 24

K&E KENNEDY & EMMETT CO. 10 X 10 JO THE 1/4 INCH 320-11



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SCHOOL OF ENGINEERING

SIAA

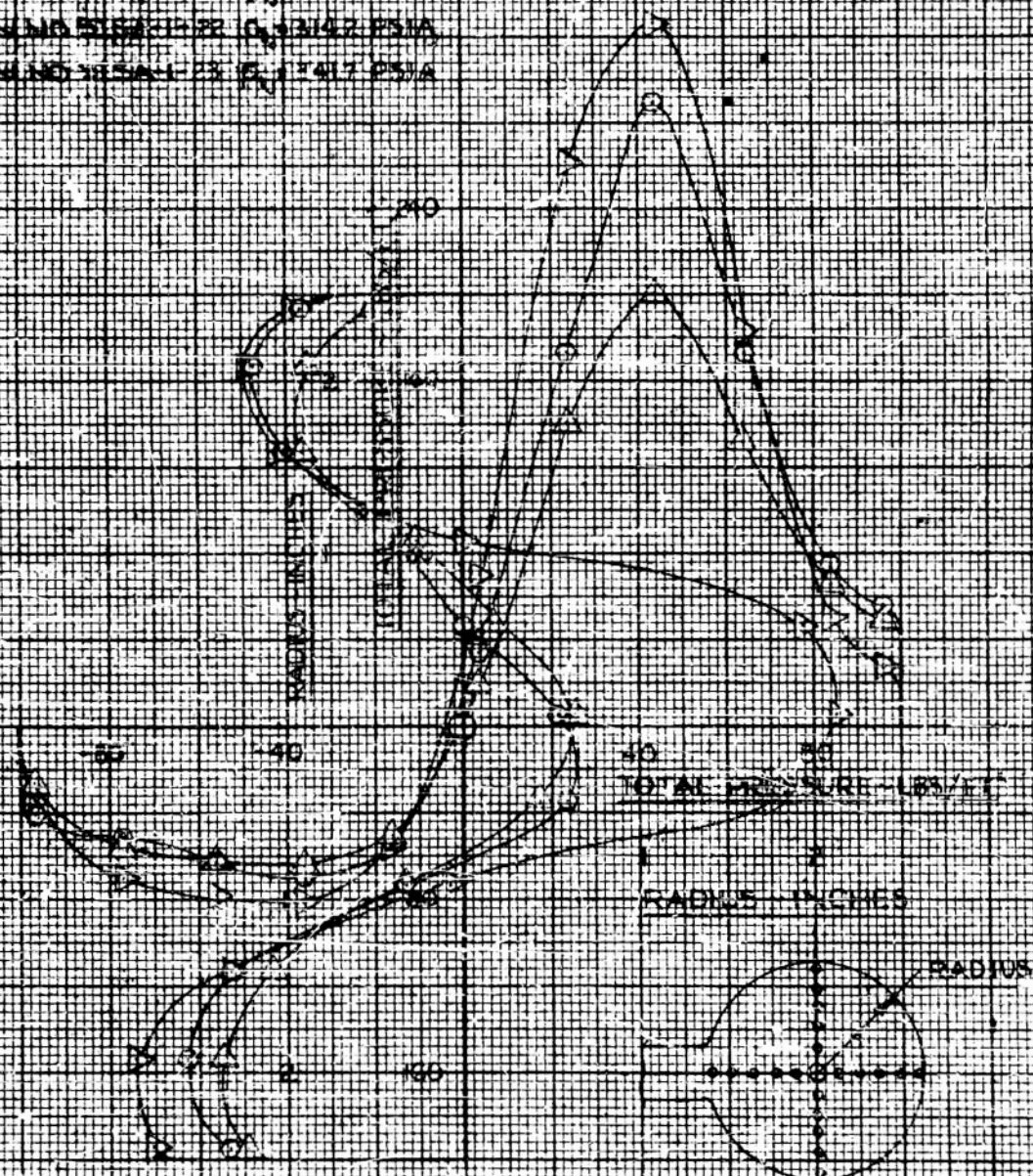
TOTAL PRESSURE

DISTRIBUTION

△ RUN NO 5156 1-21  $P_0 = 2539$  PSIA

○ RUN NO 5156 1-22  $P_0 = 2342$  PSIA

▽ RUN NO 5156 1-23  $P_0 = 2417$  PSIA



PRESSURE SURVEY

SECTION 5

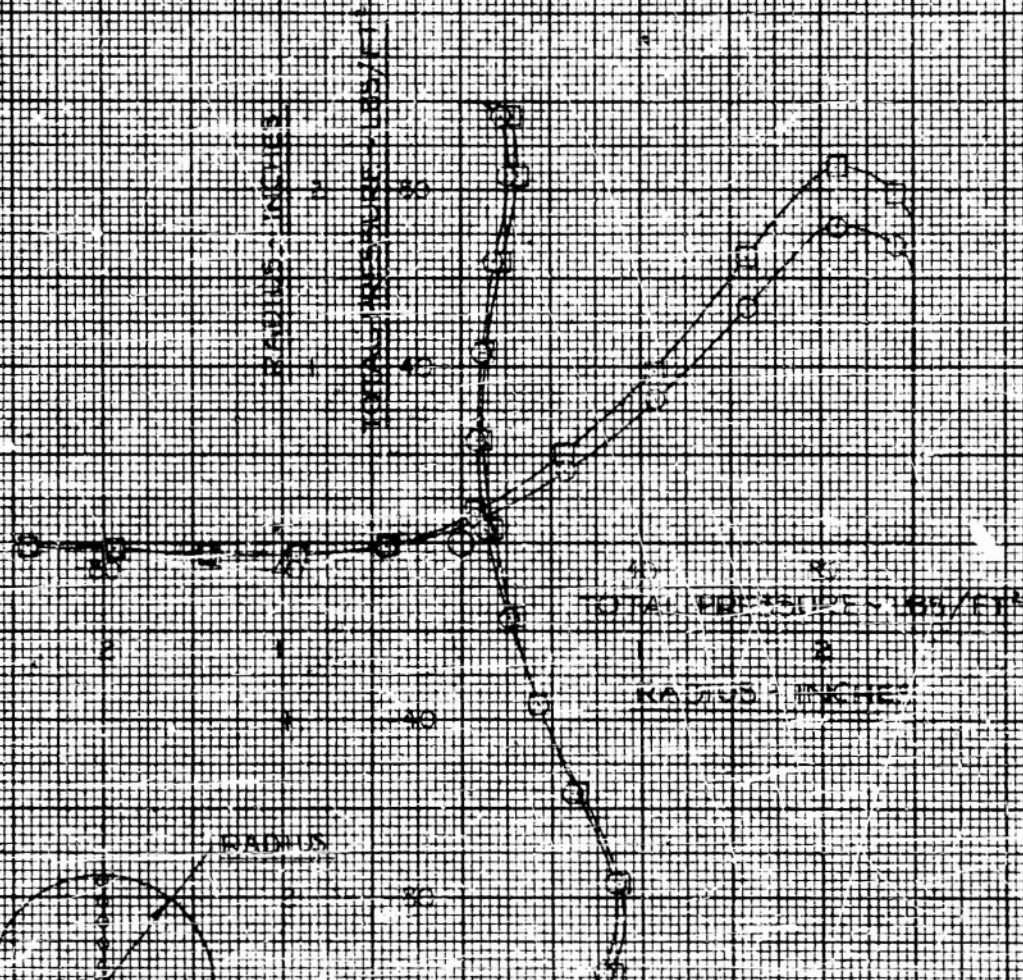
(UPSTREAM VIEW)

FIGURE 2A (CONT'D)

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SCHOOL OF ENGINEERING

DATA  
TOTAL PRESSURE  
DISTRIBUTION

- ① 12.440 PSI-A - 17.15 - 238 PSI-A  
② 12.440 PSI-A - 20.25 - 208.5 PSI-A



PRESSURE SURVEY  
POSITIONS  
(UPSTREAM VIEW)

FIGURE 24 (CONT'D)



UNIVERSITY OF WICHITA  
SCHOOL OF ENGINEERING

STAB

TOTAL PRESSURE  
DISTRIBUTION

- △ QUARTER STAB - 21.8° - 28.3 PSIA  
○ PLAIN NO STAB - 22.15° - 34.2 PSIA  
▷ PLAIN NO STAB - 23.15° - 34.2 PSIA



PRESSURE SURVEY  
POSITIONS  
(UPSTREAM VIEW)

FIGURE 24 (CONT'D)

REC'D 10/1/68

K&S

KENNEL & SHERMAN CO.  
10 X 10 TO THE 1/2 INCH

REVISED 1/68  
200-11



UNIVERSITY OF WICHITA  
SCHOOL OF ENGINEERING

STAO

TOTAL PRESSURE  
DISTRIBUTION

○ POINT NO. 215A - 19.0 PSIA 236.0 PSIA

□ POINT NO. 215A - 19.0 PSIA 1266.9 PSIA



PRESSURE SURVEY  
POSITIONS  
WICHITA UNIVERSITY

FIGURE 24 (CONT'D)

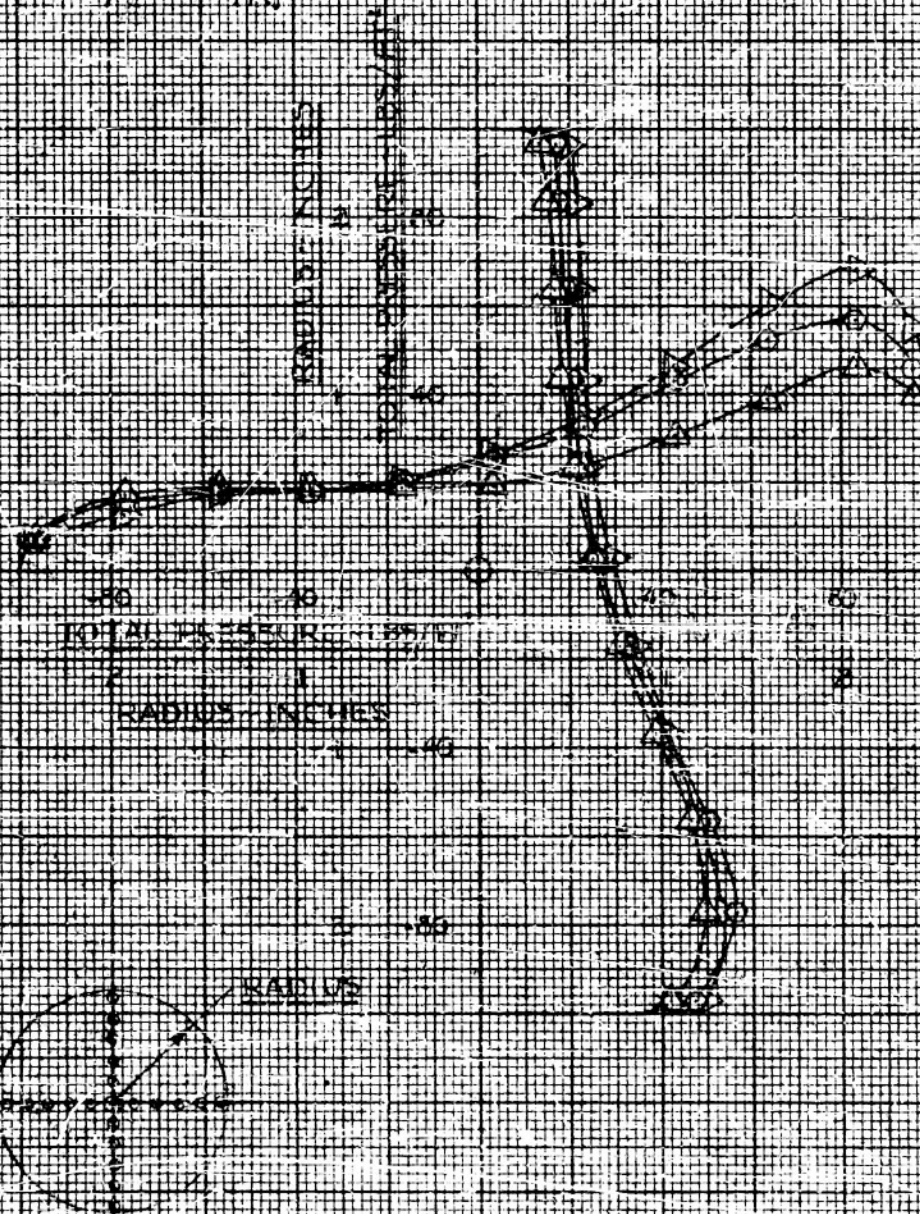
1. 2. 3. 4. 5. 6. 7. 8. 9. 10.

# DRIVERS' TV OF WICHITA DIVISION OF ENGINEERING

## STA C

### TOTAL PRESSURE DISTRIBUTION

△ RUN NO. 5181 - 10.283 PSIA  
○ RUN NO. 5182 - 10.343 PSIA  
▽ RUN NO. 5183 - 10.347 PSIA



PRESSURE SURVEY  
POSITIONS  
UPPER HALF VIEW

FIGURE 24 (CONT'D)

C. 804-7-131



UNIVERSITY OF WICHITA  
SCHOOL OF ENGINEERING

STAD

TOTAL PRESSURE

UPSTREAM VIEW

O SURVEY POINTS 1-10 2-10 3-10 4-10 5-10 6-10 7-10 8-10 9-10 10-10

CLINICAL DATA 20.0 266.9 271.0



PRESSURE SURVEY  
POINTS  
(UPSTREAM VIEW)

FIGURE 24 (CONT'D)

E. B. K. 11-12-1964

K.M.

KENT & KENT CO.  
10 X 10 TO THE 1/2 INCH

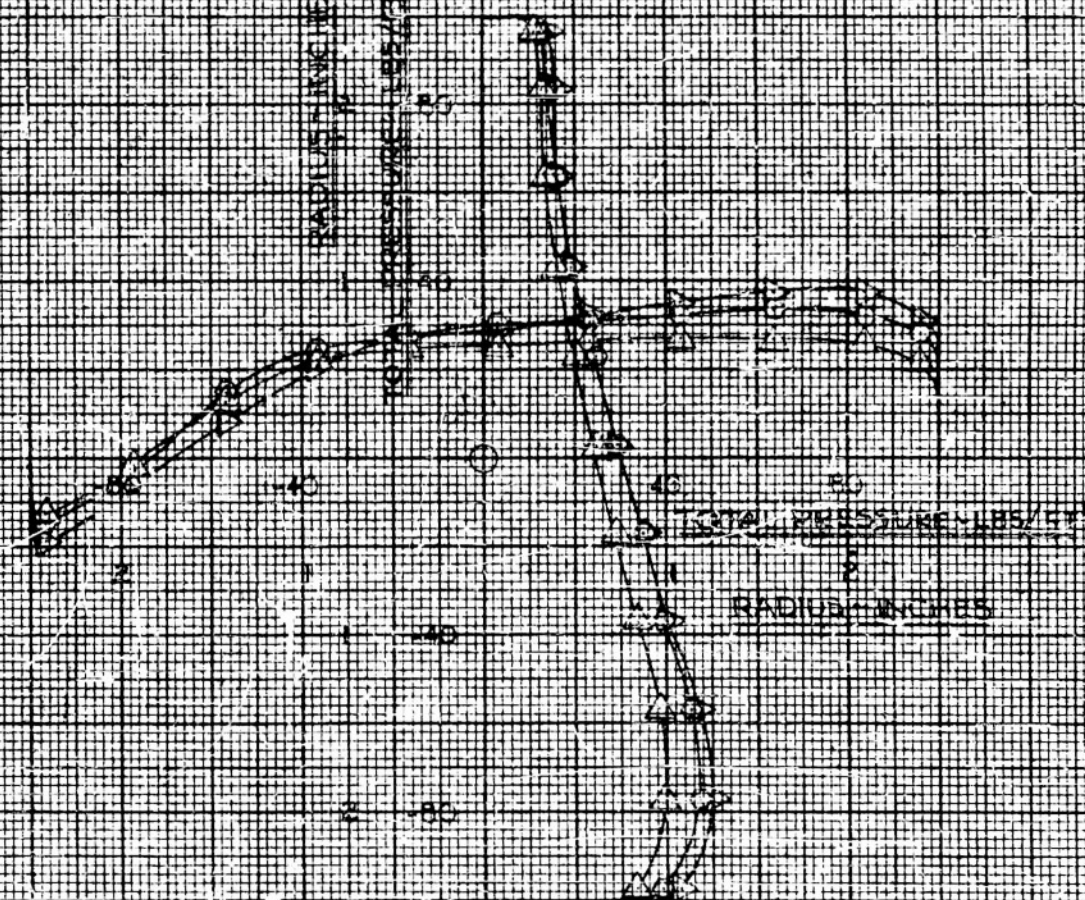
ENGINEERING  
280-11

UNIVERSITY OF WISCONSIN  
SCHOOL OF ENGINEERING

STA D

TOTAL PRESSURE  
DISTRIBUTION

- A RUN NO 573A-1-2  $P_0 = 235$  PSIA  
 C RUN NO 573A-1-2  $P_0 = 314.7$  PSIA  
 D RUN NO 573A-1-2  $P_0 = 341.7$  PSIA



PRESSURE SURVEY  
LOCATIONS  
(UPSTREAM VIEW)

FIGURE 24 (CONT'D)

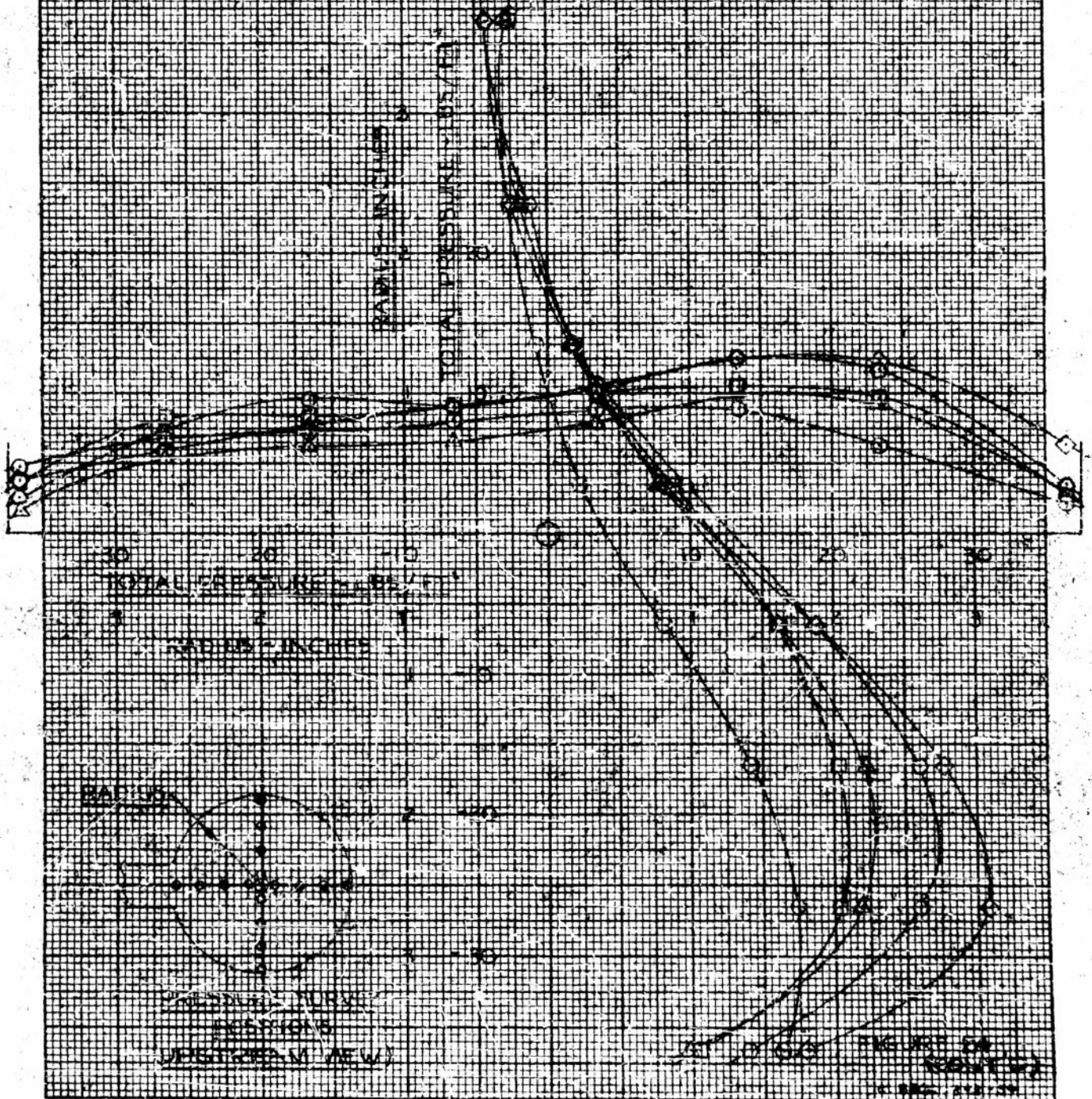


UNIVERSITY OF MICHIGAN  
SCHOOL OF ENGINEERING

STATE

TOTAL PRESSURE  
DISTRIBUTION

○ TOTAL PRESSURE - 1000 - 2000 PSI  
□ TOTAL PRESSURE - 1000 - 2000 PSI  
△ TOTAL PRESSURE - 1000 - 2000 PSI





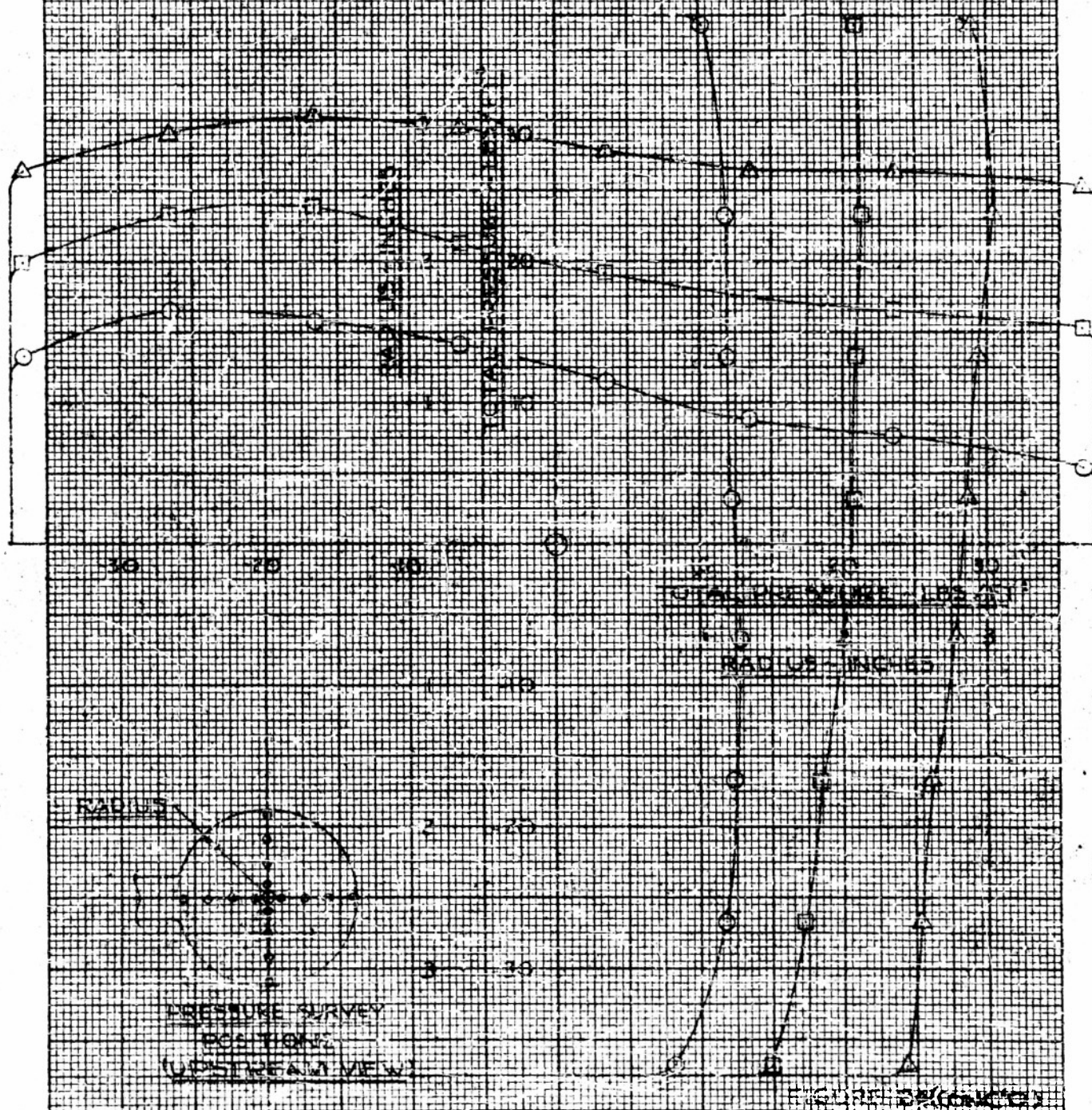




UNIVERSITY OF WICHITA  
SCHOOL OF ENGINEERING

STAFF  
TOTAL PRESSURE  
DISTRIBUTION

O RUNNER STATION 1-23  $D_2/D_1 = 1.000$   $\alpha = 1.005$   
 □ RUNNER STATION 1-24  $D_2/D_1 = .908$   $\alpha = 1.060$   
 △ RUNNER STATION 1-27  $D_2/D_1 = .824$   $\alpha = 1.066$



K&E  
KENDRICK & EDWARDS CO.  
10 X 10 10 LINE IN INCH  
200-11-  
MILWAUKEE

FIGURE 24 (CONC'D)



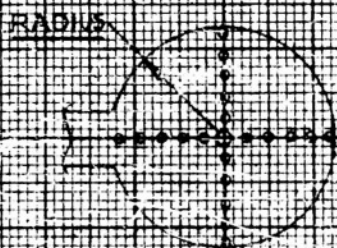
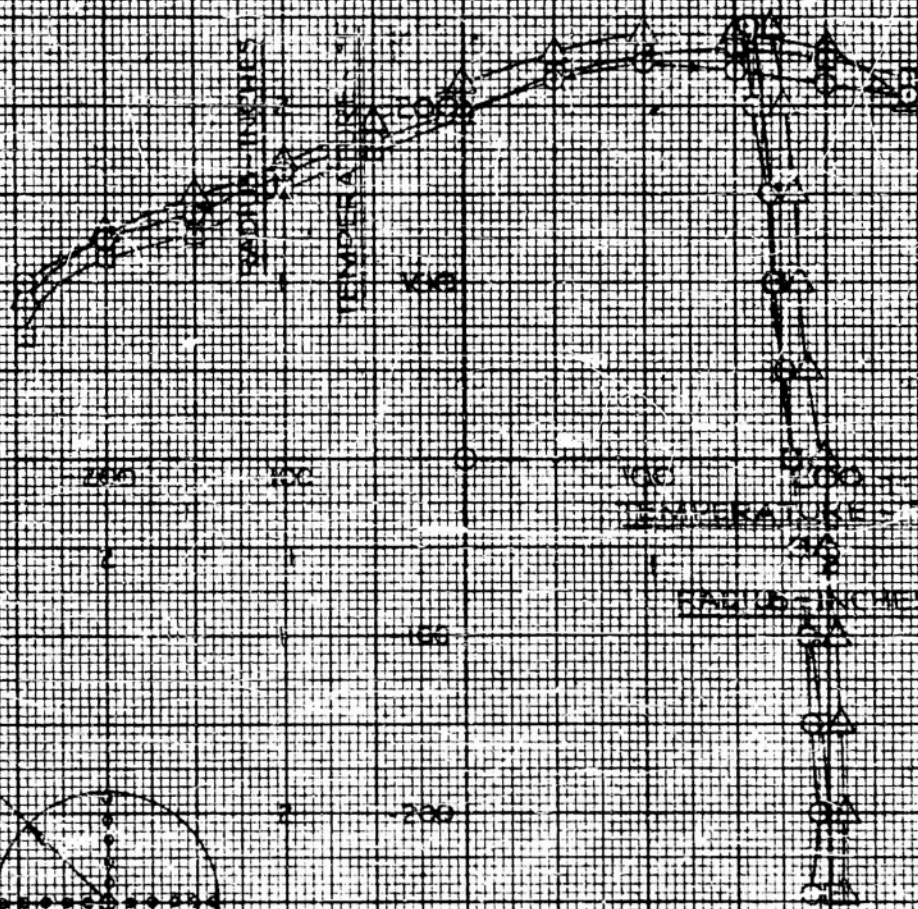
UNIVERSITY OF WICHITA  
SCHOOL OF ENGINEERING

STA A

TEMPERATURE

DISTRIBUTION

- SURFACE TEMPERATURE - 23.8 F  
□ RIVER TEMPERATURE - 25.5 F  
△ RIVER TEMPERATURE - 27.0 F



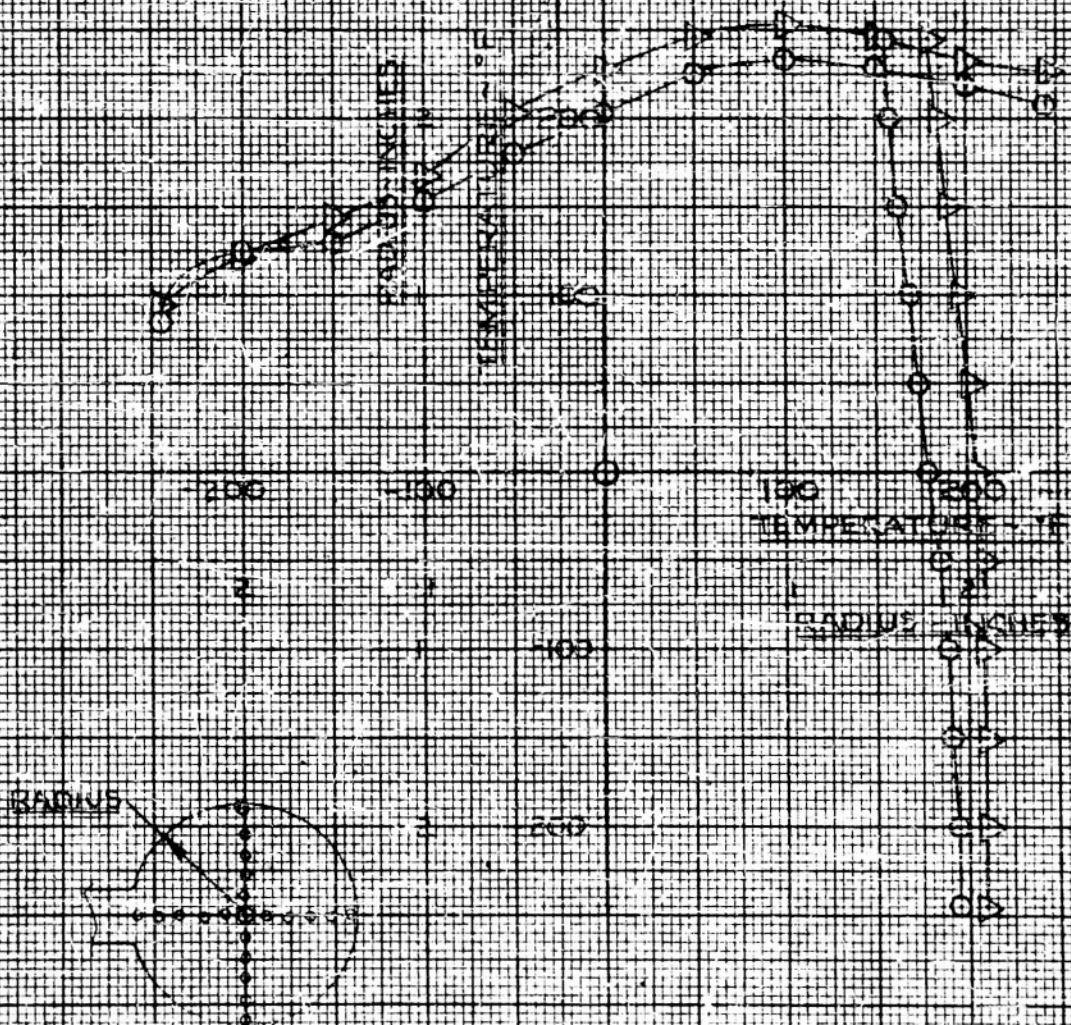
TEMP SURVEY  
POSITIONS  
(UPSTREAM VIEW)

FIGURE 25

UNIVERSITY OF WICHITA  
SCHOOL OF ENGINEERING

STIA A  
TEMPERATURE  
DISTRIBUTION

○ MAX. TEMPERATURE - 15.22 °F - 314.2 °F  
△ MIN. TEMPERATURE - 12.23 °F - 341.7 °F



TEMP SURVEY  
POSITIONS  
(UPSTREAM VIEW)

FIGURE 25 (ON P. 5)

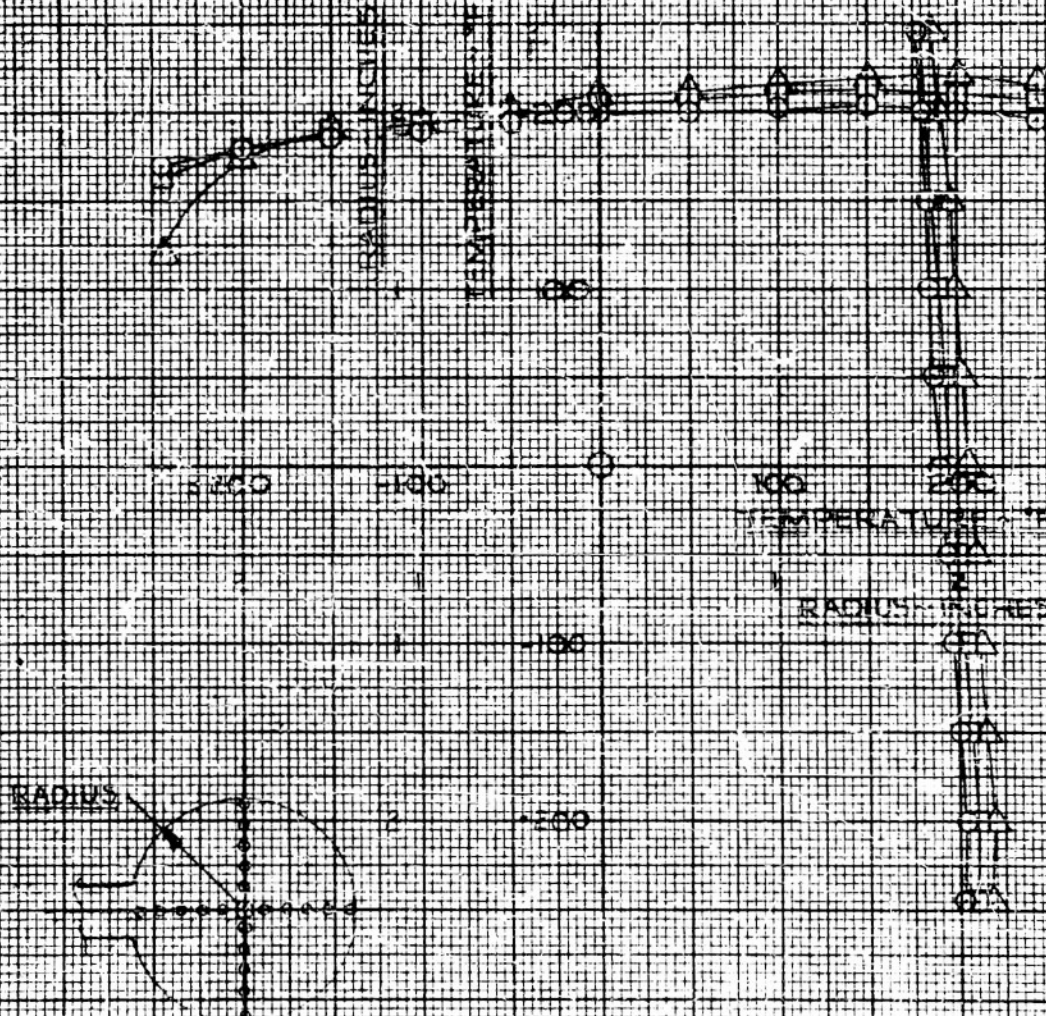


UNIVERSITY OF WICHITA  
SCHOOL OF ENGINEERING

STAB

TEMPERATURE  
DISTRIBUTION

○ PLUNGE SUPA - 19  $P_{01} = 238$  PSIA  
□ PLUNGE SUPA - 20  $P_{01} = 250$  PSIA  
△ PLUNGE SUPA - 21  $P_{01} = 289$  PSIA

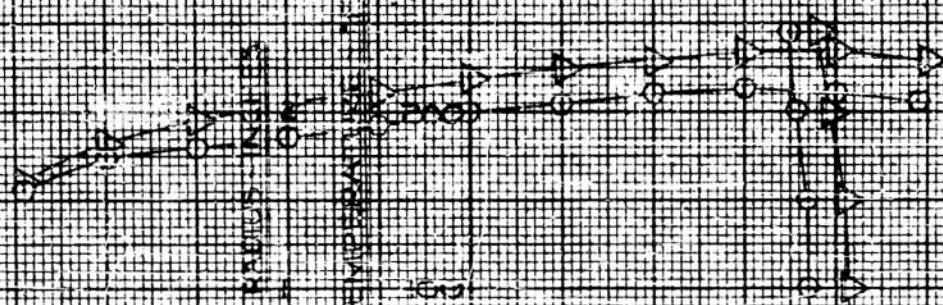


TEMP SURVEY  
POSITIONS  
CROSS-SECTION VIEW

FIGURE 23 (CONT'D)

UNIVERSITY OF WISCONSIN  
SCHOOL OF ENGINEERING  
**S A B**  
TEMPERATURE  
DISTRIBUTION

○ FURNING SIDE - 22  $P_L = 24.2$  PSIA  
△ FURNING SIDE - 25  $P_L = 24.1$  PSIA



TEMP. SURVEY  
POS. 100  
(X-STREAM VIEW)

FIGURE 25 (CONT'D)

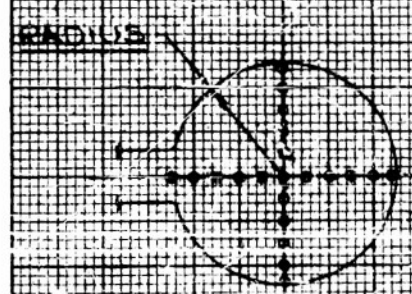


UNIVERSITY OF WICHITA  
SCHOOL OF ENGINEERING

STA C

TEMPERATURE  
DISTRIBUTION

- O FAKING STS-1-19: 2,123 BP 81A
- RUN 35-1-25: 25-0, 2465 PMA
- △ RUN 35-1-21: 21-0, 200 PMA



TEMP. SURVEY  
LOCATIONS  
(WEST REAR VIEW)

FIGURE 2-1-1

K&E  
10 X 10 TO THE 1/2 INCH  
ENGINEERING  
200-11

UNIVERSITY OF MICHIGAN  
SCHOOL OF ENGINEERING

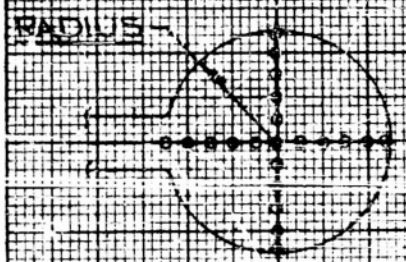
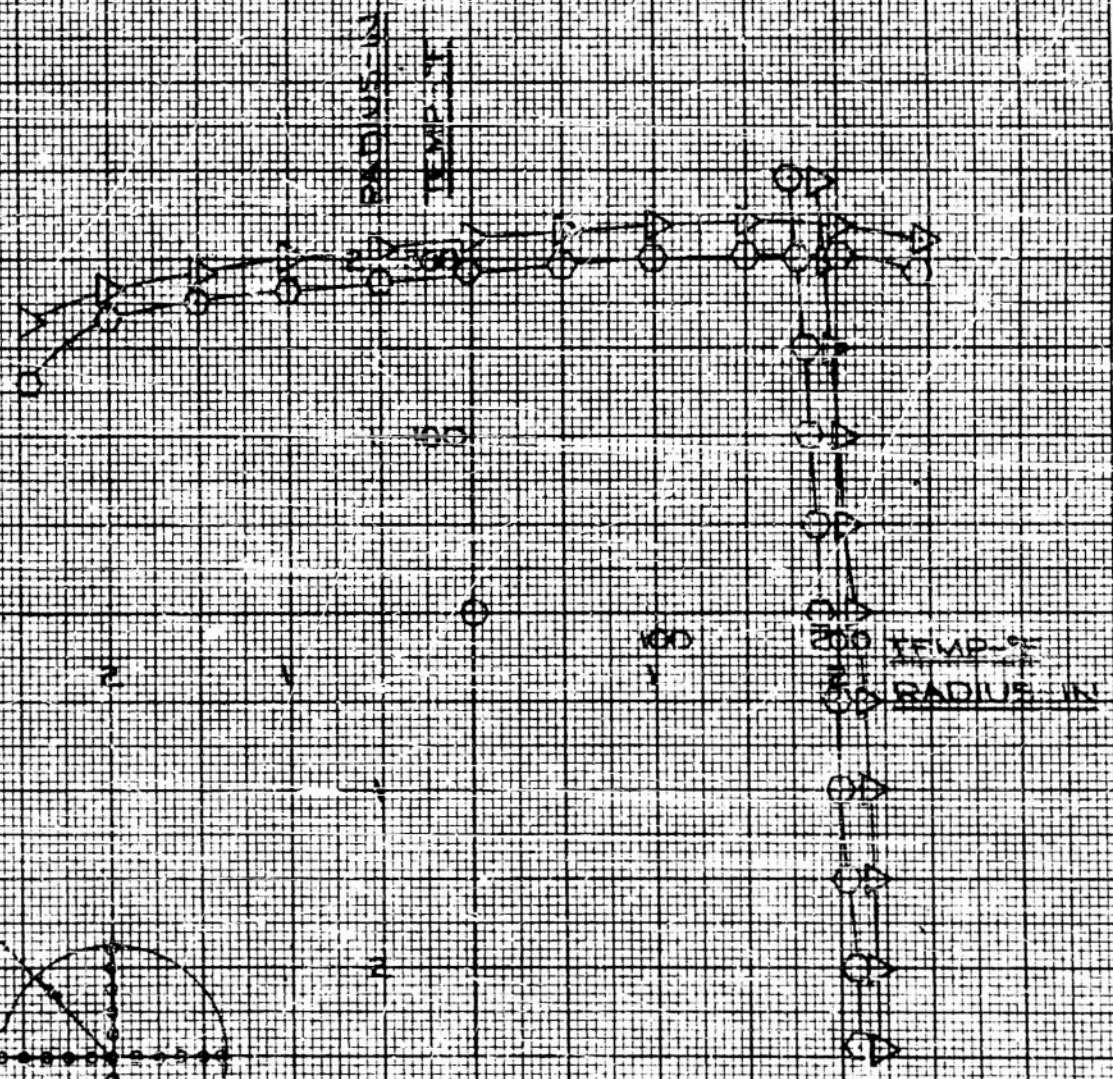
STA C

TEMPERATURE

DISTRIBUTION

O RUN NO. 5181-22,  $P_1 = 344.2$  PSIA

D RUN NO. 5181-23,  $P_1 = 341.7$  PSIA



TEMP SURVEY  
POSITIONS  
(NORTHEAST VIEW)

FIGURE 25 (CONT'D)

K&E  
KENDALL & EBERD CO.  
10 X 10 TO THE IN. (MCM)  
M2118 P. 3 V.  
389-11



UNIVERSITY OF MICHIGAN  
SCHOOL OF ENGINEERING

ETAD

TEMPERATURE  
DISTRIBUTION

- RUN NO. 615A-1-19  $P = 238 \text{ PSIA}$   
 □ RUN NO. 615A-1-20  $P = 236 \text{ PSIA}$   
 △ RUN NO. 615A-1-21  $P = 235 \text{ PSIA}$

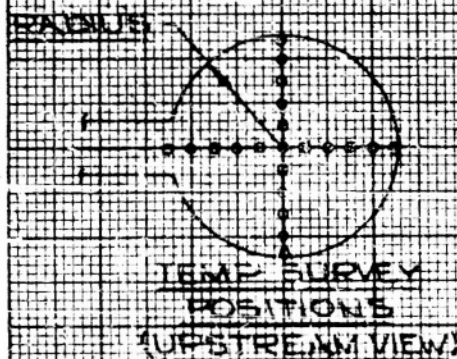
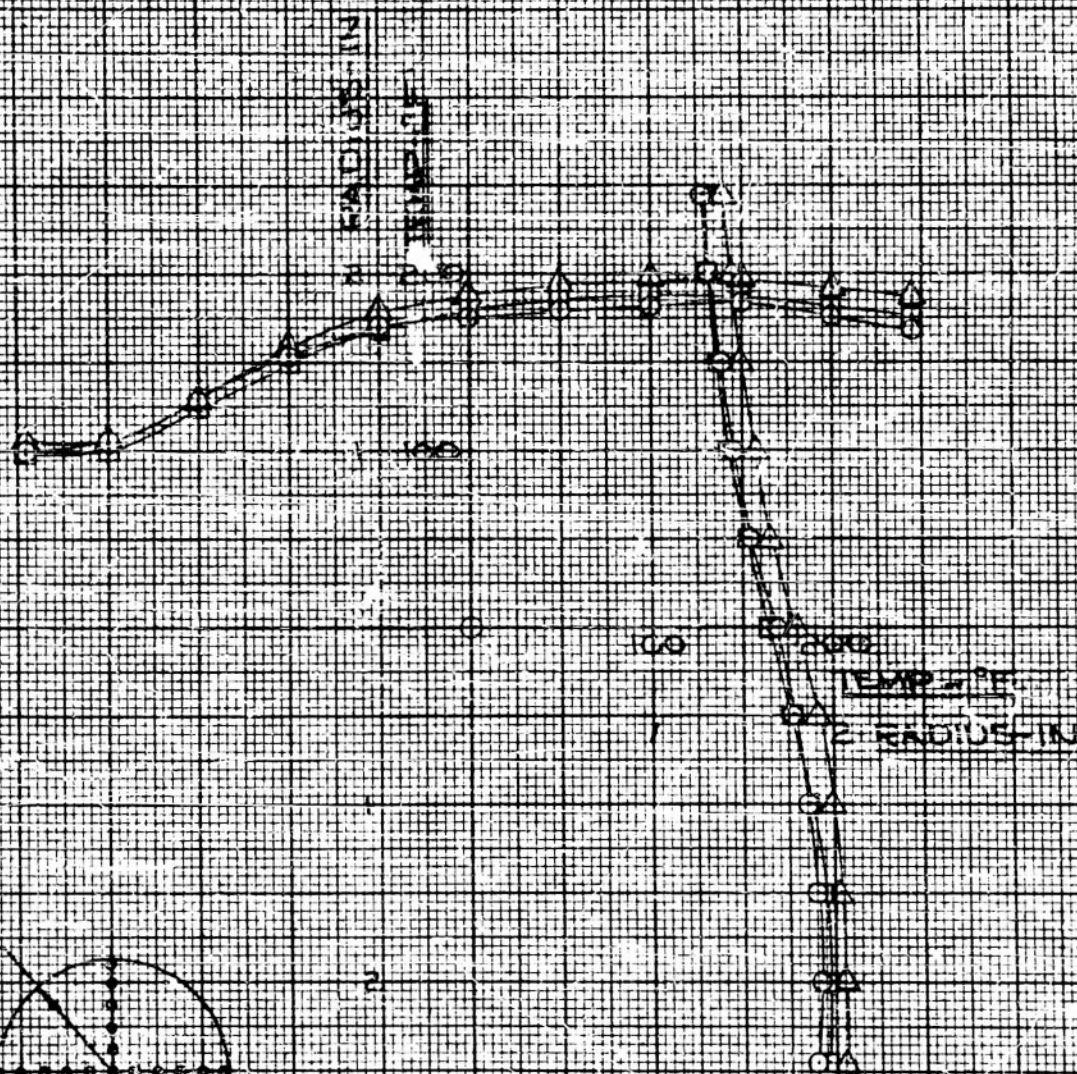


FIGURE 25 (CONTD)

K&E

PROJECT & ENGINE CO.  
10 X 10 TO LINE 1/4 INCH

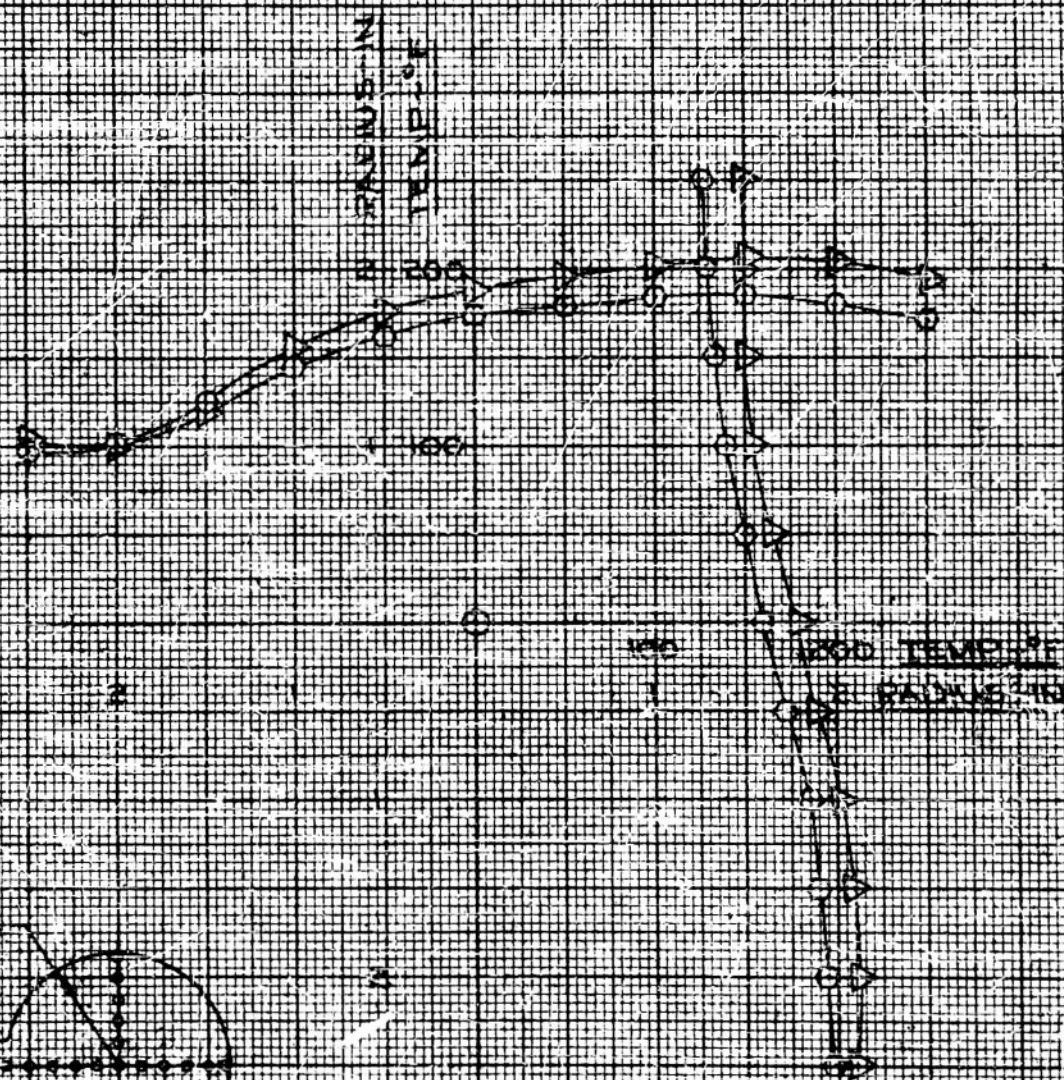
228-11

UNIVERSITY OF WICHITA  
SCHOOL OF ENGINEERING

STA D

TEMPERATURE  
DISTRIBUTION

○ RUN NO 515A-1-22 (PA) = 314.2 PSIA  
△ RUN NO 515A-1-23 (PA) = 34.7 PSIA



TEMP SURVEY  
POSITIONS  
(UPSTREAM VIEW)

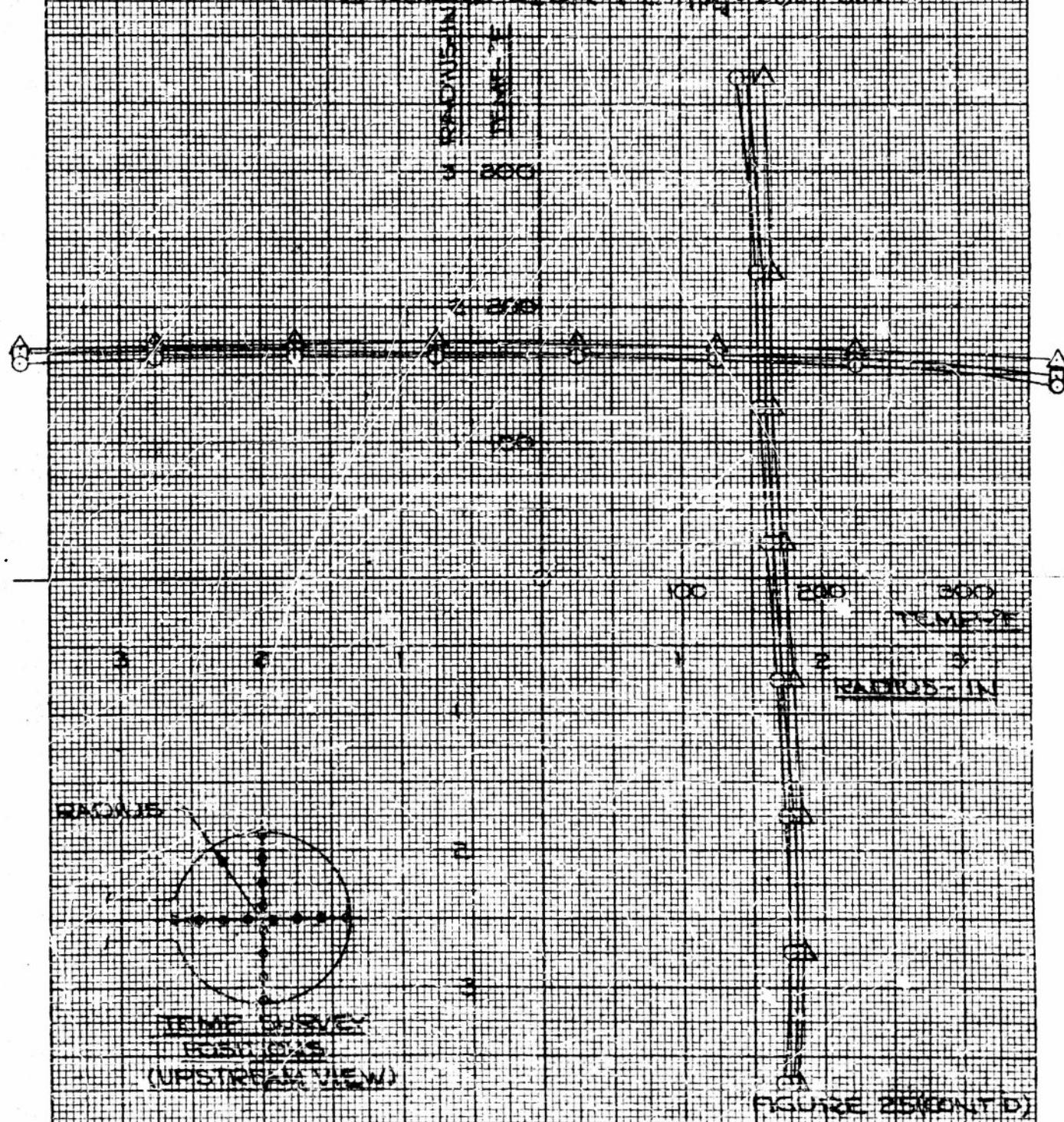
FIGURE 25 (CONTINUED)



UNIVERSITY OF WICHITA  
SCHOOL OF ENGINEERING

STATE  
TEMPERATURE  
DISTRIBUTION

O RUNING STICK-1-19  $P_{19} = 238 \text{ PSIA}$   
 C RUNING STICK-1-20  $P_{20} = 266 \frac{1}{2} \text{ PSIA}$   
 A RUNING STICK-1-21  $P_{21} = 269 \text{ PSIA}$

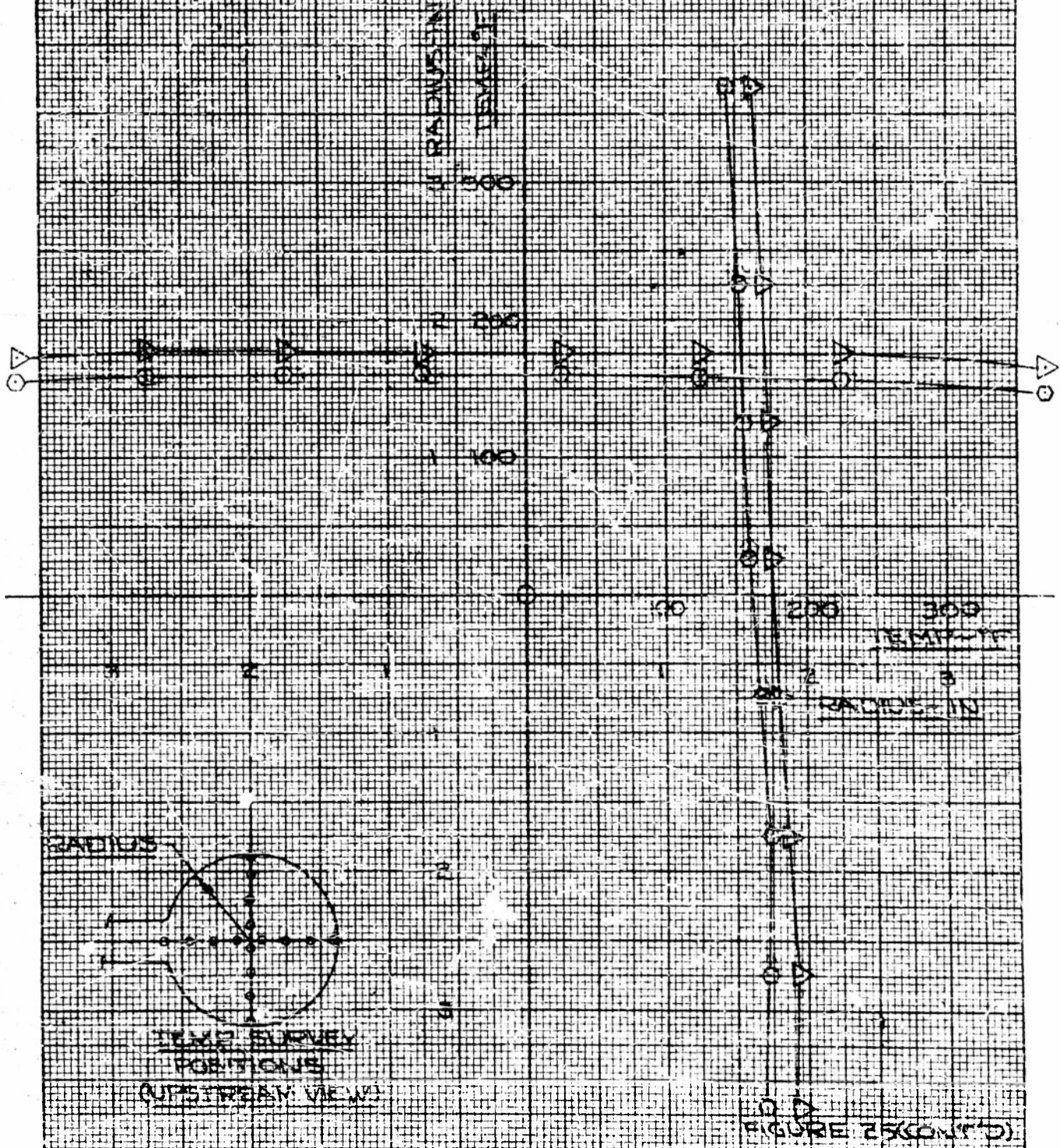




UNIVERSITY OF MICHIGAN  
SCHOOL OF ENGINEERING

STA E  
TEMPERATURE  
DISTRIBUTION

○ PLATE STRAIN - 02,  $\sigma = 814.2$  PSI  
△ PLATE STRAIN - 03,  $\sigma = 341.7$  PSI



K&E  
VENUE & ENGINE CO.  
10 X 10 TO THE 1/2 INCH  
228-11

FIGURE 25 (CONT'D)





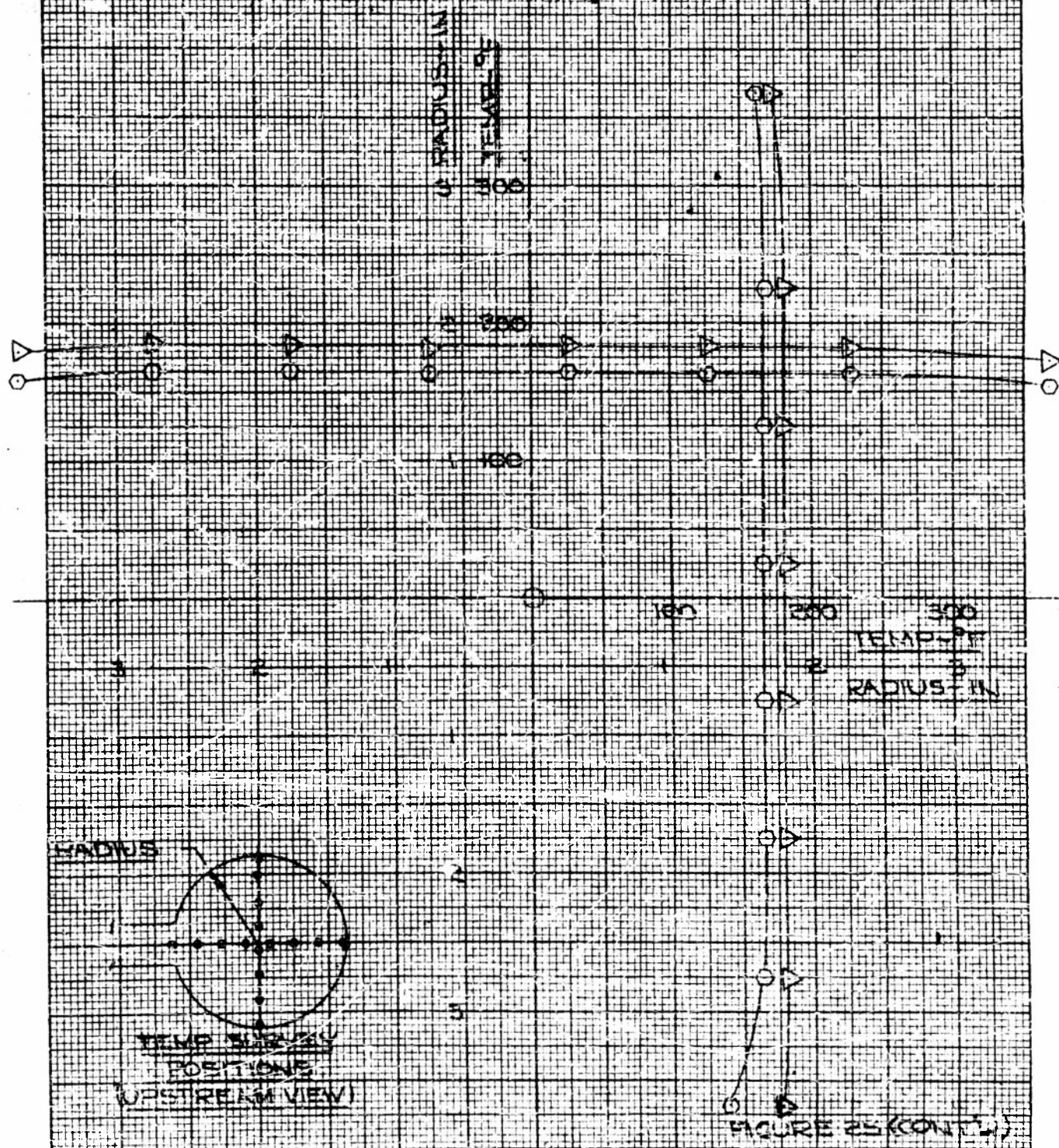
UNIVERSITY OF MICHIGAN  
SCHOOL OF ENGINEERING

STATION

TEMPERATURE

DISTRIBUTION

0.4 IN. DIAMETER - FEB 10, 1954 - 34.2 PSIA  
0.4 IN. DIAMETER - FEB 10, 1954 - 34.7 PSIA



K&E  
10 X 10 10 LINES PER INCH

200-17





UNER No. 131  
University of Wichita, School of Engineering  
PERFORMANCE TEST OF A SIDE-INLET, STEAM-TO-AIR JET  
PUMP WITH AN INBOARD NOZZLE: A.M. Heinrich.  
February 1954. 78 pp., diagrs., photos., 5 refs.

An experimental investigation was conducted to determine the performance of a side-inlet, steam-to-air jet pump with an inboard nozzle. A jet pump with a cylindrical mixing tube was tested for mass ratio, pressure ratio, and efficiency. The transfer of the available energy in the primary flow to the secondary flow and the influence on performance of controlling the direction of secondary air flow into the mixing tube were also investigated.

Performance curves are presented together with curves showing mixing-tube, cross-sectional distributions of temperature and total pressure taken at several survey stations. This report is the first in a series on jet pumps with different taper ratio mixing tubes.

I.- Aerodynamics,  
Viscous Flow  
2.- Jet Pumps  
I.- Heinrich, A.M.  
II.- UNER No. 131

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